The Great Trinity Forest Management Plan

Volume 18

Wildlife Management

Wildlife Management

Volume 18

Table of Contents

UNIVERSITY OF TENNESSEE
AGRICULTURAL EXTENSION SERVICE

PB1446

TREES FOR WILDLIFE

Rick L. Cantrell, former Extension Assistant,
Department of Forestry, Wildlife and Fisheries

William G. Minser, Research Associate,
Department of Forestry, Wildlife and Fisheries

Michael M. King, Associate Professor,
Department of Forestry, Wildlife and Fisheries

University of Tennessee
Agricultural Extension Service
Department of Forestry, Wildlife and Fisheries

Additional Photography:
Greg Wathen
Robert Wheat
Ricky Mathenia

Publication Design:
Richard Maxey

Funding for this publication was provided by the
Forest Stewardship Program

Tennessee is blessed with an abundance of forest land which provides a diversity of wildlife habitat. These habitats are composed of numerous grasses, vines, herbs, shrubs and trees. Many species of wildlife depend on certain species or types of trees and shrubs. Wildlife use trees as a food source (fruit, bark, leaves), as winter cover, for nesting, as perches and other uses. In this publication, the authors describe management practices for Tennessee landowners to consider when managing their woodlots for wildlife and timber.

WHAT IS A WILDLIFE TREE?

There are various definitions of a wildlife tree. In this publication, a wildlife tree is defined as being one that has value for wildlife for nesting, cover, perching or food production. This definition includes **den trees**, **mast-producing trees** and **snag (dead) trees**.

THE IDEAL WILDLIFE TREE

An Extension wildlife specialist once identified what he considered the ideal wildlife tree in a timber production situation. The tree was an 18-inch DBH (diameter at breast height) blackgum, was producing a large crop of berries, had a large hole high on the main stem (was mostly hollow) and had a very narrow crown that was taking up little valuable growing space. Although not valuable for sawtimber, this tree was a great wildlife tree! Ideal trees such as these may not be present in every woodlot, but when they are present, they should

DEN TREES

Den trees are live trees that contain holes or hollows large enough to shelter wildlife. Woodpeckers are credited with creating many nesting cavities in trees. Species which create these holes are called primary excavators; species such as owls, wood ducks and raccoons which use cavities created by other animals are called secondary excavators. Other mammals which typically use den trees are gray and fox squirrels, flying squirrels, opossums and black bears. Birds which use tree dens include owls, woodpeckers, bluebirds and swallows. Estimates suggest there are about 32 cavity-nesting bird species that use den trees in Tennessee. In Missouri, research has found that 89 species of wildlife use den trees and another 66 species use snags (see page 7 for discussion of snags) for feeding and perching.

The number of den trees needed in an area is dependent on surrounding conditions and landowner objectives. If, for example, the primary objective is timber production, one or two den trees per acre for wildlife may be sufficient. If the primary objective, however, is to maximize squirrel production, a landowner should leave more den trees, rather than remove them in a timber stand improvement cutting. Also, for some species, artificial nesting structures can be constructed to supplement a shortage of suitable den trees. In a young timber stand with few or no den trees, for example, gray squirrel numbers may be doubled by erecting 2-3 nesting boxes per acre. Contact your local Tennessee Wildlife Resources Agency officer or Agricultural Extension agent to obtain plans for these structures.

Fallen trees also have value for wildlife. Hollow logs provide refuge or denning opportunities to many wildlife species including shrews, mice, chipmunks, groundhogs, bears, skunks, opossums and some furbearers. During strong wind storms, trees are often uprooted. The resulting root-caps and disturbed soil also provide den sites for groundhogs, foxes, raccoons and others.

MAST-PRODUCING TREES

Mast is an important diet component of many wildlife species. Mast is the fruit of a tree or a shrub and is called “hard” (acorns, hickory nuts, walnuts, etc.) or “soft” (fleshy fruits of dogwood, blackgum, black cherry, etc.). Some of the most important trees and shrubs that produce mast in Tennessee are the oaks, dogwoods, hickories, black cherry, blackgum, beech and maples. The oaks are probably the single most important group of trees for mast production for wildlife. For squirrels, bears, wild hogs and to a lesser extent deer, oak mast appears to be the most important factor influencing reproduction. Following years of good mast production, reproduction, survival and population levels of these wildlife species are high.

Conversely, when mast failures occur, reproduction, survival and population levels of these wildlife species decline. Oak mast is also highly utilized by wild turkeys, ruffed grouse, bobwhite quail, raccoons and small rodents. Landowners should strive to maintain a variety of mast-producing trees in their woodlots to insure that food is available the entire year.

If possible, landowners should maintain trees from both the white oak and the red oak families in a forest stand because of differences in their fruiting habits. Acorns on trees in the red oak group mature in two years, while trees in the white oak group produce mature acorns in one season. By having both oak groups represented in a woodlot, there is less chance of a complete mast failure following a late killing frost in the spring. Common species in the white oak group include white oak, post oak and chestnut oak; common species in the red oak group include northern red oak, southern red oak, scarlet oak and black oak.

In addition to the oaks, it is important to plan for a diversity of other mast-producing species in the woodlot. Hickories are used extensively by squirrels and dogwood, black cherry, blackgum and wild grape are good soft mast producers. A scattering or clumps of pine provide good cover for wildlife, particularly in winter, and offer an alternate food source (pine seed). Pine also provides a valuable timber component to the timber stand.

Mast production depends on several factors, including tree species, environmental conditions, tree age and vigor. Landowners can often point out individual trees that are the best mast producers in the woodlot. If you have not observed this in your woodlot, look for some clues when selecting wildlife trees. An abundance of new or old acorns or hickory nut shells under larger trees might indicate the best producers. Temporarily mark these trees and observe their mast production for a few years to see if you are correct in your assessment; then mark the trees permanently as wildlife trees and save them.

The number of mast trees to maintain in a woodlot depends on surrounding conditions and landowner objectives. If wildlife management is the primary objective, more mast trees should be maintained than if the primary objective is timber production. In timber production areas where a complete harvesting system (clearcutting) is used, leave buffer strips along creeks and streams, as well as a few small groups of trees scattered throughout the area. Harvesting timber in smaller tracts (5-40 acres depending on the land base) will maintain adequate mast production. In general, two to three trees (larger than 12 inches DBH) in the white and red oak groups should be left per acre for good mast production for wildlife. Appendix A outlines procedures for estimating the "acorn potential" of a woodlot. Reference this section when evaluating your woodlot for mast trees.

In addition to oaks, one or two hickories and soft mast-producing trees, such as blackgum or black cherry, should also be left per acre to maximize use of the area by a variety of wildlife species.

SNAGS

Snags are dead trees at least 6 inches DBH and 10 feet tall, with little or no timber value. With the possible exception of firewood, they cannot be utilized. However, snags can be extremely valuable as feeding, perching and nesting sites for numerous species of wildlife, including woodpeckers, wrens, warblers, owls, hawks, wood ducks, mergansers, raccoons, bats, squirrels and opossums. Snag requirements differ by species. Distinction is made between hard (some value as marketable wood) and soft (advanced stage of decay) snags. Hard snags become soft snags if they are left alone and not removed from the woodlot. Soft snags are critical for a majority of snag-dependent wildlife. Snags take up very little growing space and should be left uncut whenever possible (see Figure 1 for snag management recommendations). Three to seven dead or dying trees should be left for wildlife use. Snags should also be left in waterfowl management areas for use as perches and nesting sites.

Figure 1. Recommendations for snag management by Evans and Conner for North Central and North Eastern Forests

* Manage for maximum feasible rotation length
* Consider old growth a high priority
* Leave 1/4 acre permanently uncut clumps in each 3-1/3 acres harvested
* Discontinue removal of dead, dying and decayed trees—leave for snags
* Consider constructing artificial nesting boxes
* Leave buffer strips along both sides of streams
* Leave shelter belts

REFERENCES AND RECOMMENDED READING

Byford, J.L. 1986. Building bird houses. Univ. Tennessee Agric. Ext. Serv. Spec. Publ. SP293D. 6 pp.

Crawford, H.S. and R. L. Marchinton. 1989. A habitat suitability index for white-tailed deer in the Piedmont. Southern Journal of Applied Forestry 12 (1):12-16.

Evans, K.E. and Conner, R.N. 1979. Snag management. IN: Management of North Central and Northeastern forests for nongame birds. USFS Gen. Tech. Rpt. NC. 51. North Central Forest Exp. Stn., St. Paul, MN. 262 pp.

Kitts, J.R. 1981. Snags for wildlife. Extension folder 581. Univ. Minnesota Agric. Ext. Serv. 4 pp.

Titus, R.L. (Chair). 1985. Management of snags and cavity trees in Missouri. Habitat Management Series No. 2. Missouri Department of Conservation and U.S. Forest Service. 21 pp.

APPENDIX

JUDGING YOUR ACORN POTENTIAL*

Abundance of oak acorns is one of the most important factors affecting the suitability of mixed oak woodlands for deer, turkey, and squirrels. Here is a way to judge your woodland's potential for producing acorns for wildlife.

1) Pick a few areas that seem to be representative of your woods and mark off a circle about 60 feet in radius. This approximates a one-quarter acre plot.
2) Count all oak trees 10 inches or larger DBH (diameter at breast height) inside the plots. These are your best producers. Separate your counts into 2-inch diameter classes (10, 12, 14, etc.).
3) Calculate basal area (BA) of each diameter class using the figures listed in Table 1. For example, if you have six oaks that are 12 inches DBH, multiply 6 by 0.79. (6 x 0.79 = 4.7).
4) Add all the basal areas together and multiply by 4 to get an estimate for one acre.

Table 1. Basal area of trees by 2" diameter classes.

DBH	Basal Area
10"	0.55
12"	0.79
14"	1.07
16"	1.40
18"	1.77
20"	2.18
22"	2.64

* Published by Neal Wilkins in University of Tennessee Forestry Renewable Resources Timely Tips, Vol. 5, No. 3 (July 1989). Adapted from Crawford, H.S. and R. L. Marchinton. 1989. A habitat suitability index for white-tailed deer in the Piedmont. Southern Journal of Applied Forestry 12 (1):12-16.

ACORN INDEX

The acorn potential index presented in Table 2 is based on a top score of 100. If your condition is rated fair or poor but you have many oaks smaller than 10 inches DBH, just wait and give them time to grow. This method can be simplified by foresters using a BAF 10 or 20 prism and simply calculating BA/acre of all oaks greater than 10 inches DBH. Please keep in mind that this is only an index. For example, trees that inherently produce a large number of flowers, grow on forest edges or grow in the open may produce greater numbers of acorns. You can get more detailed information about the potential of your woodlot, with respect to wildlife and timber production, from the Tennessee Wildlife Resources Agency, Tennessee Division of Forestry and the University of Tennessee Agricultural Extension Service.

Basal Area Score	Acorn Potential
Below 40	Poor
40 - 60	Fair
60 - 80	Good
80 - 100	Excellent
Over 100	Excellent but may need thinning

PB1446-4M-6/94
R12-1041-08-001-94

Great Trinity Forest Management Plan

Wildlife Management

Bird Nighttime Roosts

Bird Nighttime Roosts[1]

Joe Schaefer and Sarah Miller[2]

Birds roosting in large numbers at nighttime can cause several problems. Airplanes are more likely to crash if they strike many birds at once. Large flocks of birds can also have a significant impact on grain fields, or crop fruits such as cherries and grapes. Bird droppings under a large roost site can be a considerable nuisance. Birds calling from their perches before sunrise are annoying to people sleeping nearby.

WHY BIRDS ROOST

Communal roosting provides several advantages for birds. This phenomenon provides an opportunity for birds to find mates and to sharpen communication skills they use throughout the year. Some birds, because of their age or familiarity with the surrounding landscape, may be more efficient at finding food. Less experienced members of a roost can follow other birds to known feeding sites. Roosting flocks also provide a form of protection from predators. Birds occupying the center of the flock are less exposed to predators than those on the edges.

Several bird species roost in groups of hundreds or thousands. These roosting flocks may be composed of a single species or of several species. Birds that commonly roost in large numbers include starlings, house sparrows, crows, grackles, gulls, purple martins, red-winged blackbirds, pigeons, vultures and wading birds.

TYPES OF ROOSTS

Birds roost in a variety of natural areas and man-made structures. Natural roosting sites can include trees in urban parks and residential areas, haystacks, ivy, hedgerows, and marshy areas. Man-made structures chosen for roosting often include barns, ledges, chimneys, attics, flat roofs, airport hangers and runways.

LEGAL CONSIDERATIONS

The legal status of each bird species may vary on federal, state and local levels. As non-native species, house sparrows and starlings are not protected by federal or state law. However, local ordinances may require permits for controlling these species. Migratory birds, such as gulls, are protected by federal and state law. **It is illegal to poison wildlife in Florida.** Regardless of their legal status, all birds must be treated as humanely as possible. Cruelty to animals is prohibited by Florida Statute 828.12.

CONTROL METHODS

Each roost site is unique and may require individual attention by a professional to determine the appropriate control methods. Contact the State Director of Animal Damage Control, U.S. Dept. of Agriculture, APHIS (Animal, Plant, Health, Inspection Services; 904/377-5666).

Control methods consist of 2 basic types: mechanical and chemical. Because each roost is unique, methods that work in one situation may not work in another. No single method has proven to be a cure-all for roosting problems. Using several methods together usually results in greater success. Refer to Table 1 for control methods recommended for various roosting species.

Mechanical Control Methods

Exclusion options

1. Design new buildings or alter old ones to eliminate horizontal resting places, such as designing 45° angle ledges or constructing beams in barns for **catwalks** so cats can patrol bird roosts.
2. Apply **porcupine wire** (metal prongs) or sticky repellents (bird glue) on ledges or rafters. Covering the ledge with masking tape before applying the bird glue makes removal of the sticky substance easier.
3. Hang **heavy plastic (PVC) strips** in large door openings of warehouses. This method allows for human traffic while excluding birds.
4. Cover high value crops, such as fruit trees, with plastic **bird netting**.

Habitat Modification options

Prune small branches so that trees become less suitable roosting sites for small birds.

Frightening device options

1. Visual or auditory frightening devices include recorded bird distress calls or alarm calls, gas-operated exploders, battery-operated alarms, exploding shotgun shells (shell-crackers), firecrackers, lights, bright objects, eyespot balloons, scarecrows, and motorized hawks. Most birds adapt quickly so devices must be diversified and their locations shifted constantly.
2. Avitrol® is registered in several bait formations as a chemical frightening agent. Use is restricted to government agencies, pest control operators, and persons under their supervision. Birds that eat treated bait behave erratically and give warning cries that frighten other birds from the area. This chemical is lethal and connot be used without a permit from the Florida Game and Fresh Water Fish Commission.

Trapping options

As with all control methods, special care must be taken in trapping so that non-target birds are not affected, particularly migratory birds which are protected by federal and state laws. All non-target birds caught accidently in traps must be released immediately.

1. **Funnel traps** are the most commonly used for house sparrows. Funnel traps should be checked frequently.
2. **Automatic traps** are counterbalanced multicatch traps. House sparrows enter a compartment then are dropped into a lower compartment from which there is no escape. Enticing birds into the trap may be more difficult than the funnel trap, but overall catch is usually greater.
3. **Trigger traps** are limited in the number of birds they can catch at one time. Some are not automatic and require a person to spring the trap at the proper moment.
4. **Decoy traps** are used to catch starlings where they congregate. Place 10 to 20 well fed and watered starlings in the cage as decoys. The feeding and calling of decoy starlings will draw others to the cage.

Shooting options

Shooting is often ineffective because of the small number of birds killed relative to the numbers usually involved in problem roost situations. The sound of shooting is more effective for dispersing birds from an undesirable roosting location. It can be a helpful technique when employed to supplement or reinforce other methods used in a dispersal program. This is not an option for migratory bird problems (see "Legal Considerations"). Local ordinances also may prohibit this option.

Chemical Control Methods

Repellent options

1. Some chemicals such as Mesurol® can be used as a **taste aversion** method against birds. This material can be applied on fruit crops, such as cherries and grapes, and may repel birds by making them sick.
2. No effective repelling odors have been developed.

Toxicant options

It is illegal to poison wildlife in Florida.

Fumigant options

No fumigants are registered for control of birds.

Pesticide Information Numbers

Contact the following for information on pesticide (chemical) use for bird control in Florida:

- IFAS Pesticide Information 904/392-4721
- Florida Department of Agricultural and Consumer Services, Pesticide Information 904/487-2130

Suppliers

When the appropriate methods have been determined for a problem roost, supplies can be obtained from the following sources.

Porcupine Wire

- Nixalite of America
- 1025 - 16th Avenue
- Box 727
- East Moline, IL 61244
- (309) 755-8771
- Shaw Steeple Jacks Inc.
- 2710 Bedford Street
- Johnstown, PA 15904
- (814) 266-8008

Sticky Substances

- Bird Control Internat. Corp.
- P.O. Box 12
- Macedonia, OH 44056
- (216) 425-2377

Netting

- Almac Plastics Company
- 6311 Erdman Ave.
- Baltimore, MD 21205
- (301) 485-9100
- Animal Repellents, Inc.
- P.O. Box 999
- Griffin, GA 30224
- (404) 227-8222

Chemical Frightening

- Avitrol® Corp.
- 320 S. Boston Ave., Suite 514
- Tulsa, OK 74103

- (918) 582-3359

Kites, Balloons, and Other Frightening Devices

- Local sources - lawn & garden, hardware, and feed stores.
- Wildlife Control Technology
- 6408 S. Fig Street
- Fresno, CA 93706
- (209) 268-1200
- Bird-X
- 325 W. Huron Street
- Chicago, IL 60610
- (312) 648-2191

Traps

- Tomahawk Live Trap Co.
- P.O. Box 323
- Tomahawk, WI 54487
- (715) 453-3550

REFERENCES

Arnold, K.A. 1981. "Environmental control of birds." *CRC Handbook of Pest Management in Agriculture*, Vol. I (D. Pimentel, Ed.). CRC Press, Boca Raton. pp. 499-505, 597 pp.

Boudreau, G.W. 1975. *How to Win the War with Pest Birds*. Wildlife Technology, Hollister. 174 pp.

Dolbeer, R.A., P.P. Woronecki, A.R. Stickley, Jr., and S.B. White. 1978. "Agricultural impacts of a winter population of blackbirds and starlings." *Wilson Bulletin* 90:31-44.

Grussing, D. 1980. *How to Control House Sparrows*. Roseville Publishing House, Roseville. 52 pp.

Solman, V.E.F. 1981. "Birds and aviation." *Environmental Conservation* 8(1):45-51.

Stokes, D.W. 1979. *A Guide to the Behavior of Common Birds*. Little, Brown and Co., Boston. pp. 261-274 Thearle, R.J.P. 1968. "Urban Bird Problem." *The Problems of Birds as Pests* (R.K. Murton and E.N. Wright, Eds.). Academic Press, New York. pp. 181-197

Tables

Table 1.

Table 1. Control Methods of Birds by Species									
	Species								
Control Method	Starlings	HouseSparrows	Crows	Grackles	Gulls	PurpleMartins	Black-birds	Wading birds	Vultures
Catwalks	X	X							
Porcupine wire	X	X	X		X				X
Plastic door strips	X	X							
Netting				X		X	X		
Prune branches	X			X		X	X		
Frightening devices	X	X	X	X	X	X	X	X	X
Funnel traps		X							
Automatic traps		X							
Trigger traps	X	X							
Decoy traps	X	X	X				X		
Shooting	X	X							
Taste aversions	X			X			X		

Footnotes

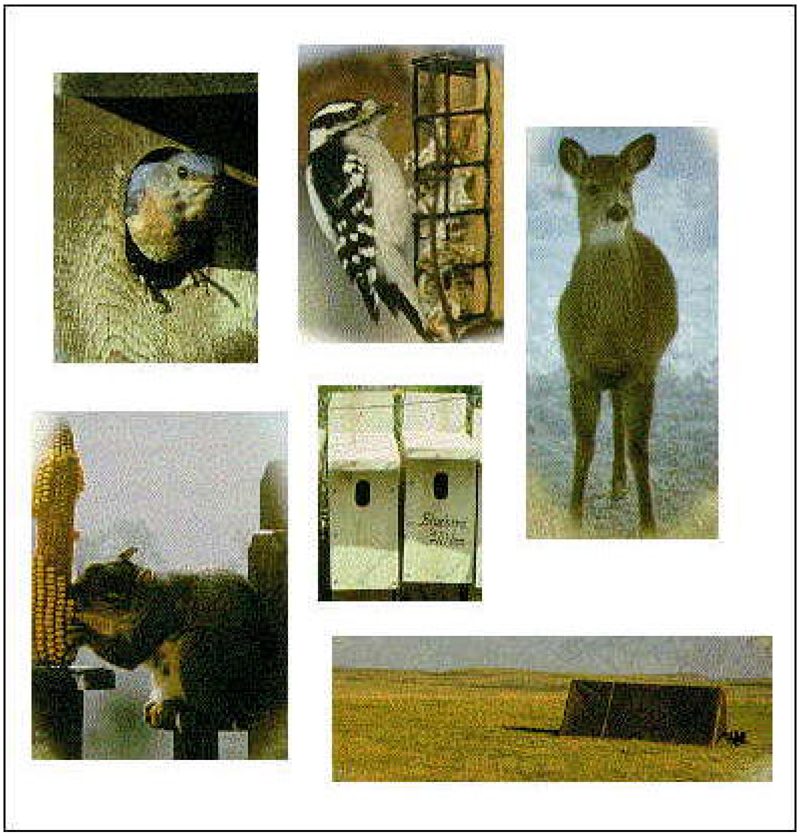
1. This document is SS-WIS-53, one of a series of the Department of Wildlife Ecology and Conservation. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Published: originally as "Nighttime Bird Roosts". Minor Revision: August, 2001. Please visit the EDIS Web site at http://edis.ifas.ufl.edu

2. Joe Schaefer, urban wildlife extension specialist; Sarah Miller, wildlife assistant Wildlife and Range Sciences Department; Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville FL 32611.

Copyright Information

Building Nest Structures, Feeders, and Photo Blinds for North Dakota Wildlife

by
Chris Grondahl
and
John Dockter



State Game and Fish Department
100 North Bismarck Expressway
Bismarck, North Dakota 58501-5095

Table of Contents

Produced by the
North Dakota Game and Fish Department's
Nongame Program

Credits
Thanks to Carrol L. Henderson of the Minnesota DNR for contributing artwork from *Woodworking for Wildlife*. Thanks to Linda Roeder for organization and layout of this publication.

Photos
by Chris Grondahl and Harold Umber

Introduction

Providing nesting areas, feeding, and watching wildlife are becoming increasingly popular sports in North Dakota. These activities generate about 18 million dollars annually to our state. More importantly, these pastimes provide hours of relaxation, entertainment, and enjoyment for both young and old alike.

This publication introduces some types of nest structures, feeders, and photo blinds which can be constructed in your home at a minimal expense.

There are four sections to this publication. The first covers nest boxes and platforms. These structures are meant to enhance existing habitat or provide a nest structure where none presently exists. This does not mean that natural habitat is not important. Dead and dying trees which provide nesting cavities are still the best type of habitat available.

The second section describes wildlife feeders. Feeding birds and mammals in the winter can be good for both you and wildlife. First, it provides you a pastime and viewing opportunity during the cold winter months. Secondly, wildlife may have difficulty finding adequate food and this additional source can help them survive the winter. Remember, planting a crop for feed is just as good, or better, than grain in a feeder.

Section three is a short description of predator guards which are very important additions to any wooden support post.

The final section describes two types of homemade photo blinds which can be made with minimal effort or dollars spent. If you've never tried a photo blind, you may be surprised at the results.

Nest Boxes and Nesting Platforms

General Information for Nest Boxes and Nesting Platforms

Providing nesting areas for wildlife is a popular and growing hobby for many North Dakotans. Building houses according to the proper specifications, placing them in the right habitat, and maintaining them can benefit both bird and mammal populations. If they are not monitored for detrimental species such as the house sparrow, they may actually do more harm than good.

It is important to realize that not all birds and mammals nest in cavities. Many birds, like the American robin or meadowlark, either build cupshaped nests in trees or nest on the ground. The nest box plans that are found in this publication are specific to wildlife that utilize a cavity, either within a dead or dying tree or a man-made structure such as a nest box.

Cavity nesting birds will accept any kind of nest box that they can enter. Before deciding on what kind of nest box to build, there are considerations which should be taken--the size of the entrance hole, interior dimensions, proper ventilation, and the capability to open the nest box for monitoring and cleaning. Do not construct a box for "birds" in general as most species require different sized houses and entrance holes. The following guidance and construction plans will provide specific plans for most North Dakota species.

For all practical purposes, wood is the only appropriate building material to use. Wood is a natural material with good insulating properties. Plastic and metal often overheat. Green "pressure-treated" lumber is impregnated with copper arsenate as a preservative. If the chemical is not applied perfectly, the wood is toxic to birds and humans. Exterior grade plywood contains dangerously high levels of formaldehyde and therefore is also not the best choice. The best woods to use are rough cut cedar or redwood. They naturally resist deterioration when exposed to sun and rain and the weathered look is inconspicuous and attractive.

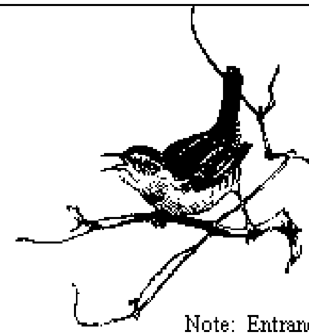
Never paint or stain the inside of a nest box. If you want to paint the exterior, close up the box and paint only what you can see. Use an exterior grade latex paint and give the top a second coat. Choose a light shade which reflects most heat or a natural color such as green, tan, or gray. A heavy grade of linseed oil stain works well also. Houses that blend in with their surroundings are more appealing than brightly painted boxes and less likely to draw the attention of human vandals.

Nest boxes can be mounted in several ways. They may be attached to existing wood or metal fence posts, power or telephone poles, existing trees, or on wood or metal posts or pieces of pipe used specifically for this purpose. Utility poles are often suitable for mounting nest boxes; however, permission should be obtained from the utility companies before this is done. Discretion should also be used before mounting to trees. Do not place bird boxes designed for bluebirds on trees because this invites competition from too many other species.

Predator-proofing should, be considered for all bird nest boxes that are not mounted on steel fence posts or pipe. A piece of sheet metal, tin, or used aluminum plates from newspaper offices serve well to prevent predators from climbing wooden posts. Sheets should be stapled or screwed on around the outside of the wood post be at least 12 inches high. The bottom of the guard should be at least two feet above ground level.

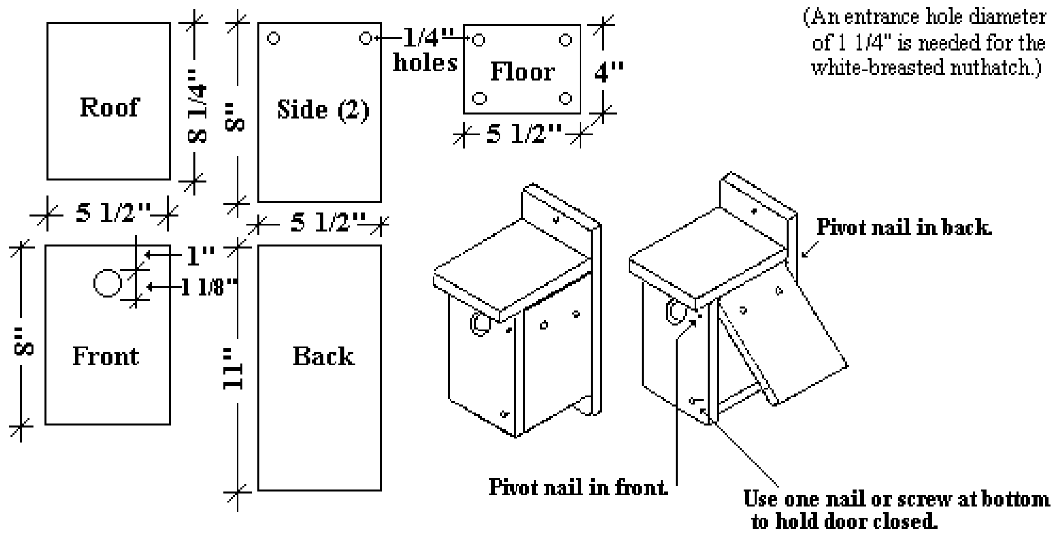
Do not put perches on any bird houses. Only the unwanted house sparrows and starlings prefer perches. If house sparrows or starlings begin nesting in a bird house tear out the nest material as these species are not protected by state or federal law. Nests may need to be removed numerous times before these birds abandon their efforts.

House Wren*, Black-capped Chickadee*, White-breasted Nuthatch

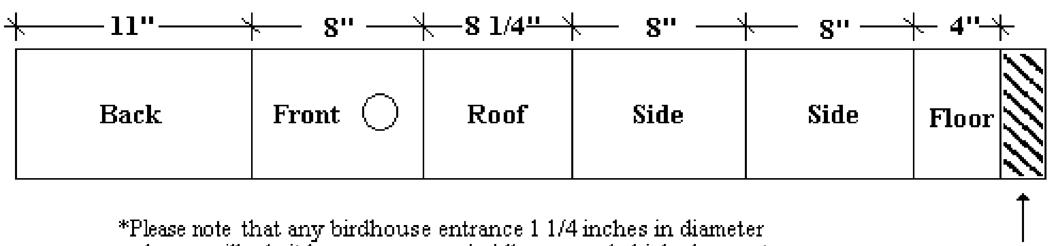


Note: Entrance hole diameter is 1 1/8".

(An entrance hole diameter of 1 1/4" is needed for the white-breasted nuthatch.)



Lumber: One 1" x 6" x 4'0".

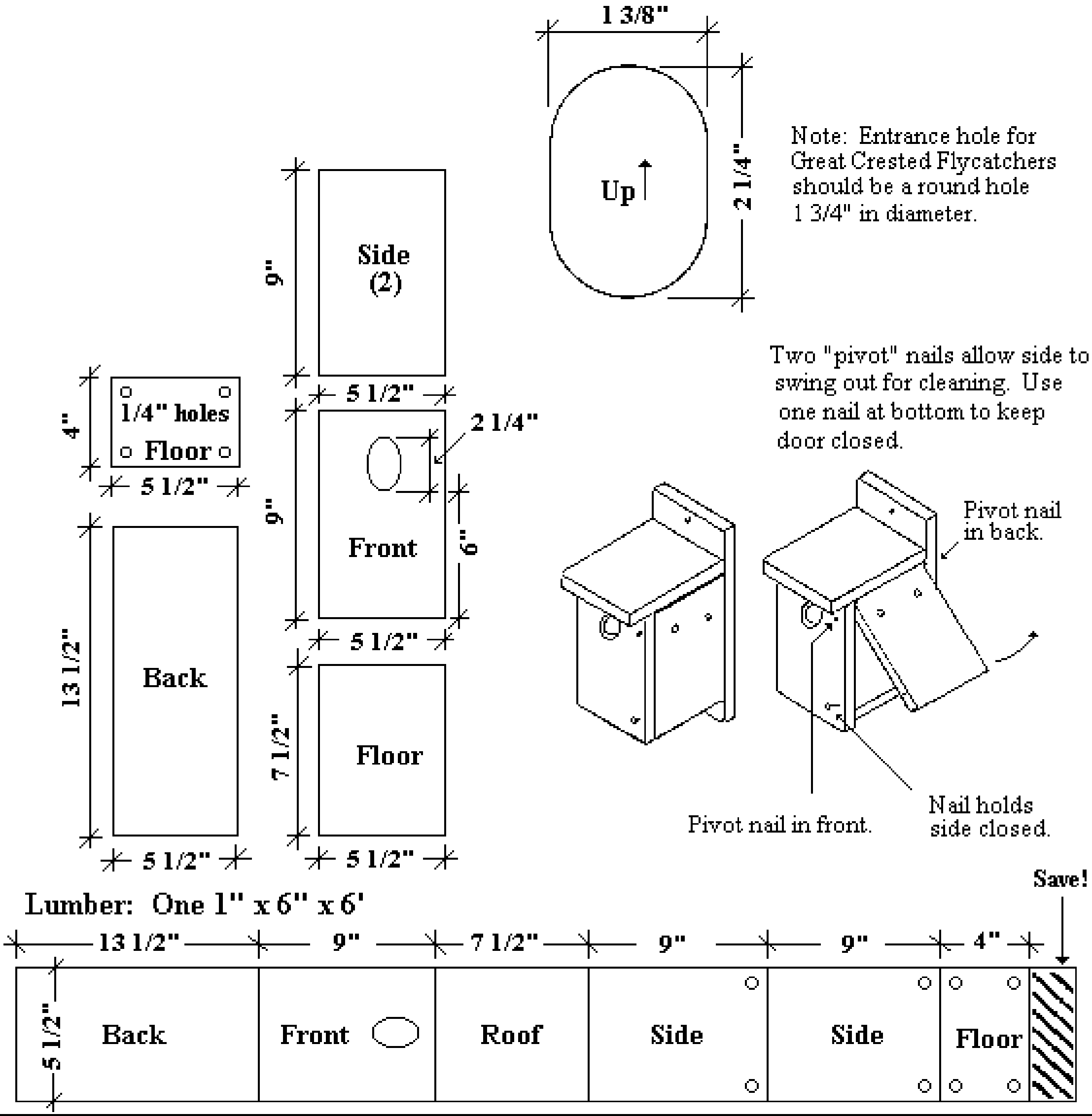


Save!

*Please note that any birdhouse entrance 1 1/4 inches in diameter or larger will admit house sparrows! All wren and chickadee nest boxes should have an entrance hole of 1 1/8 inches in diameter.

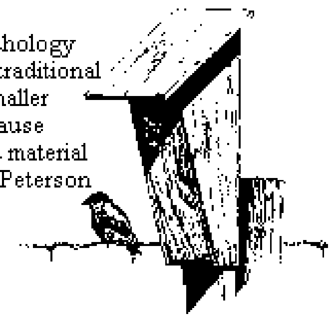
Tree Swallow and Eastern Bluebird

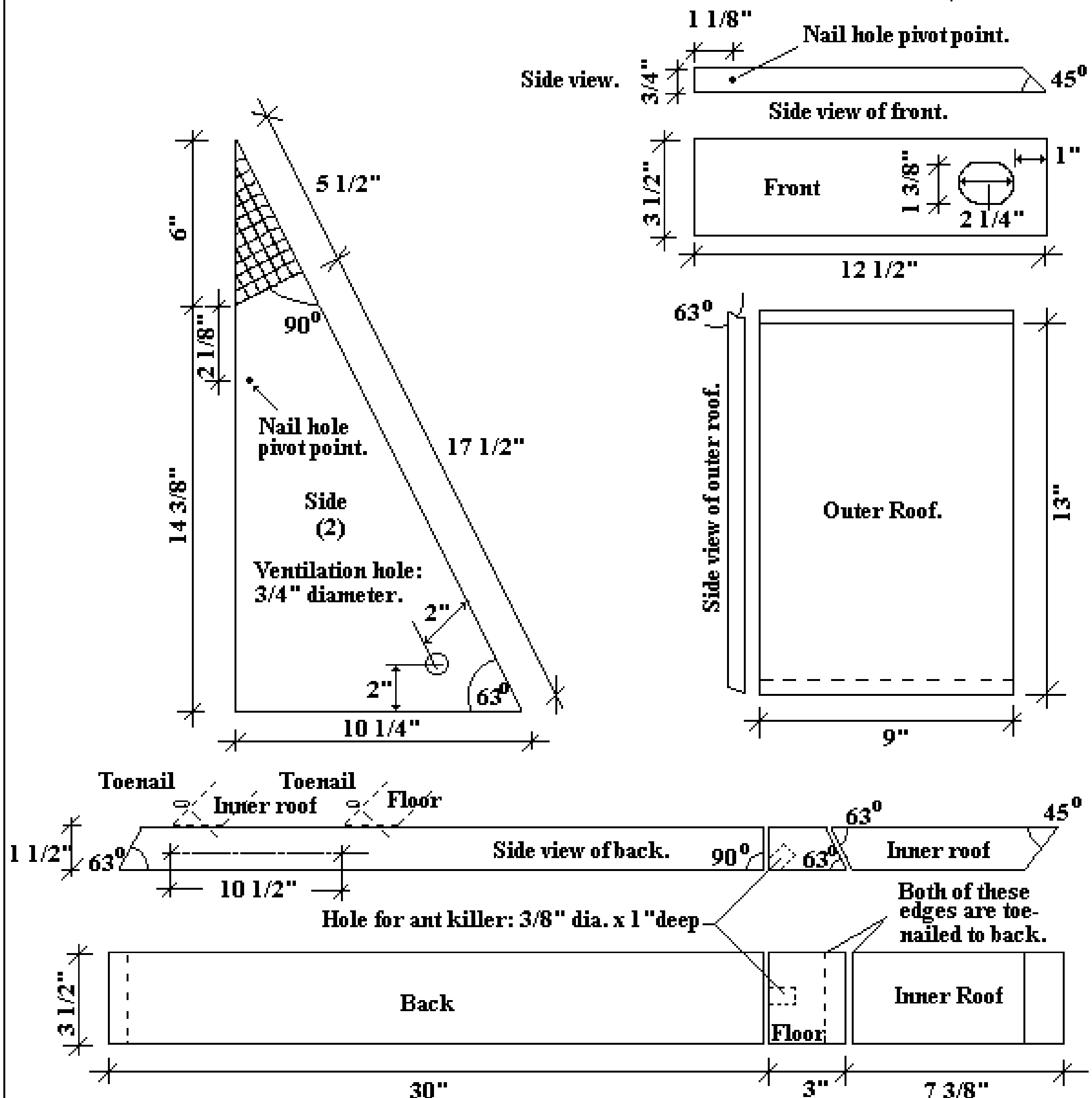
Eastern bluebirds nest throughout North Dakota. The best habitat consists of areas comprised of short grasses with nearby fence posts, high line wires, or sparse trees where birds can perch. Bluebirds normally will not nest within city limits or farmsteads where competition from house sparrows is intense. For best results, nest boxes should be placed in pairs about 10-25 feet apart and 100-200 yards between pairs. They should be put 4-6 feet above the ground on steel posts or wood posts with predator guards. The entrance hole should face in a general northeast direction to prevent sun from shining in and over-heating the box.



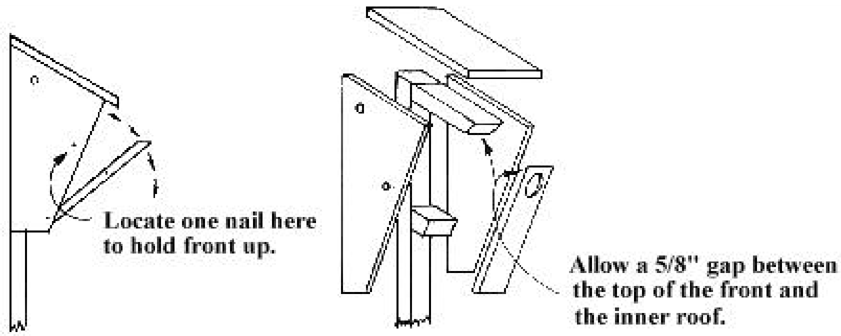
Peterson Bluebird House

The most recent data presented by W.H. Davis in the Journal of Field Ornithology in 1996 suggests that eastern bluebirds prefer this style of house over the traditional rectangular box. Bluebirds seem to prefer the oval entrance and slightly smaller floor area of the Peterson house. This design is more difficult to build because of the angled cuts required. It is also more costly because of the increased material involved. Personal preference also plays a part in nest box choice and the Peterson house is often chosen for its appearance.

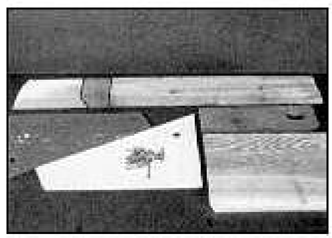




Peterson Bluebird House (continued)



A. The Peterson house has seven parts and is assembled in this order:

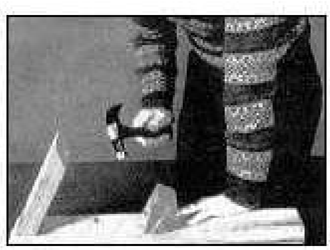


A

B. The inner roof is toe-nailed to the back.

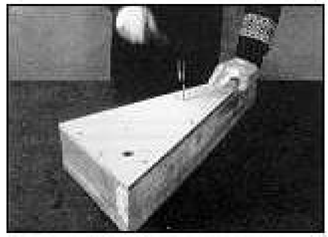
B

C. Then the floor is toe-nailed to the back.



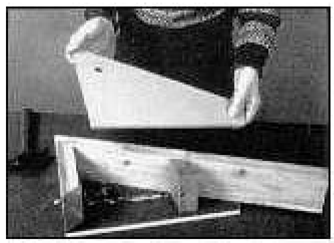
C

D. Third, one side is nailed to the resulting frame.



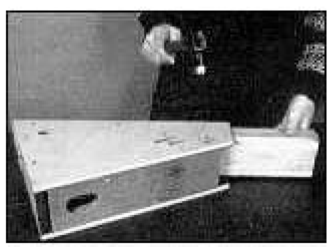
D

E. Then the other side is nailed to the frame.



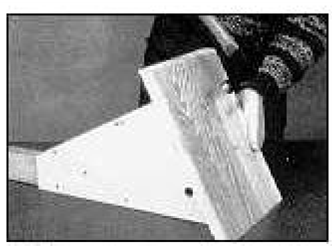
E

F. Next, the swing-down front is fastened by a nail into each side. A third nail is pounded part way into the side near the entrance hole. This is removed each time the house is a checked.



F

G. Finally, the outer roof is nailed on top.

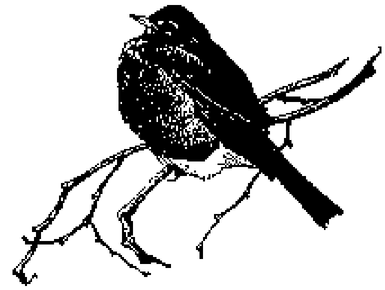


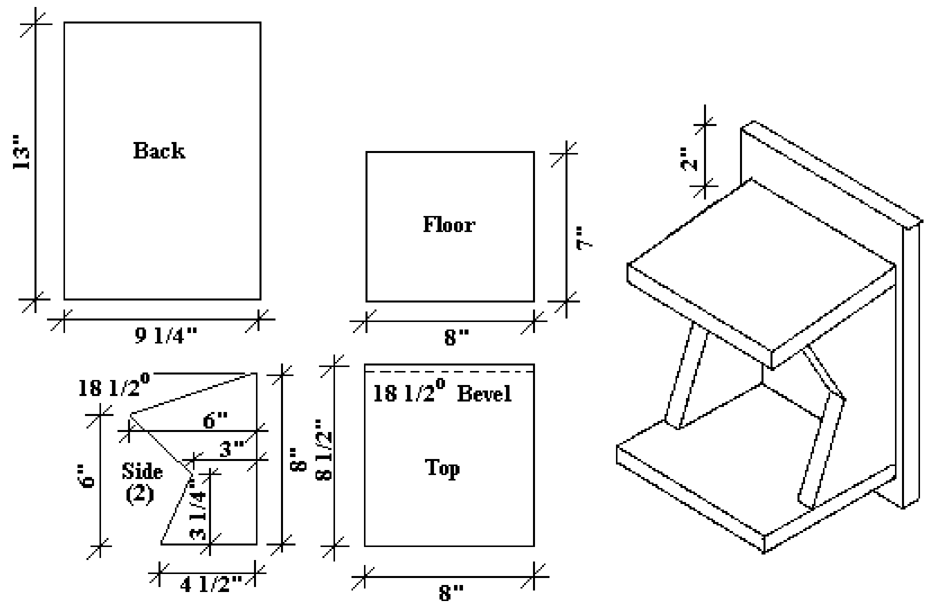
G

Editor's Note: *-- Good sanitation and maintenance of the nest box at the end of the breeding season are your best defenses against ectoparasites and other insects. To repel blowflies, wasps and ants during the breeding season, some researchers recommend using a pyrethrin insecticide as the safest pesticide.*

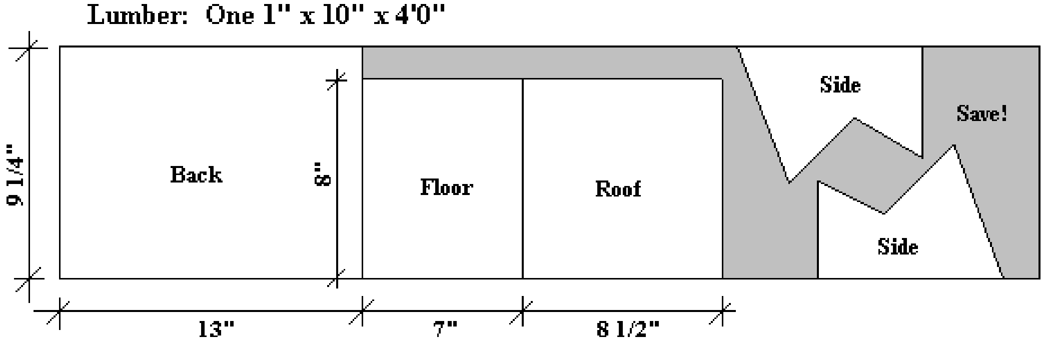
American Robin and Barn Swallow

The American robin is one of the most commonly known urban birds and is a joy to welcome back in the spring. A shelf as described below can be placed on the wall near a window where the birds can be observed throughout the nesting season or to a tree trunk or post 6-10 feet above the ground. Barn swallows will also utilize this shelf structure and may be encouraged to nest away from a doorway or other inconvenient location if presented with this opportunity.

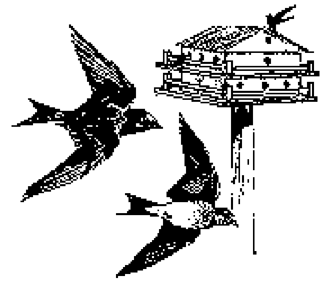




Lumber: One 1" x 10" x 4'0"



Purple Martin House

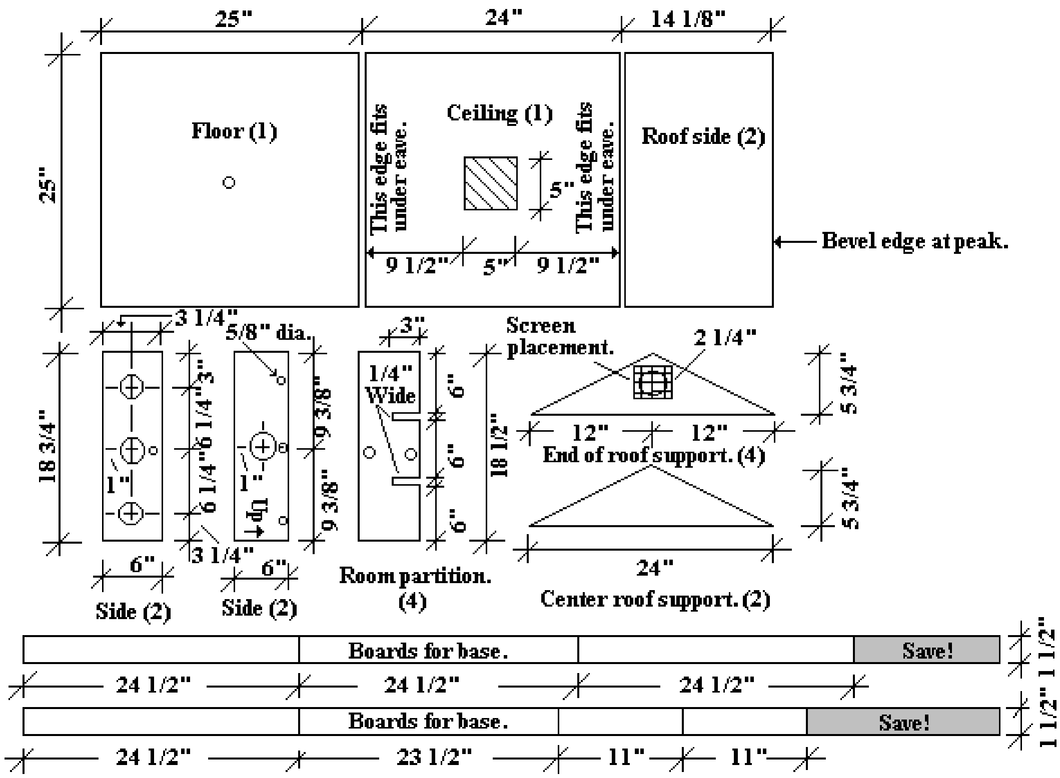


Attracting this insect eating bird is one of the biggest challenges for any backyard bird enthusiast. As the first martins arrive in mid-April, remove the entrance covers to the house which kept out starlings and sparrows during the winter. Ensure that your house is in an open area at least 30 feet away from trees and open on all sides. Martin houses should be at least 8 feet above the ground and painted white to reflect the sun. Houses need to be cleaned out after each season. House sparrows must be controlled if you are to be successful since the house sparrow is the martin's worst enemy.

Materials:

4' x 8' x 1/4" plywood
2" x 2" x 6" for chimney
1" x 2" x 14' for base
1" x 1" x 8' for corner blocks
4" x 8" metal window screen
4" x 4" x 14' cedar post

Place 1/2" dowel railing around balcony to keep young from falling.



Purple Martin House

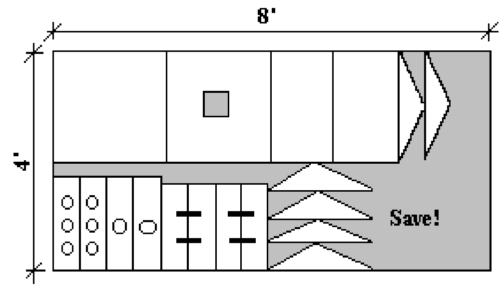
(continued)

CONSTRUCTION

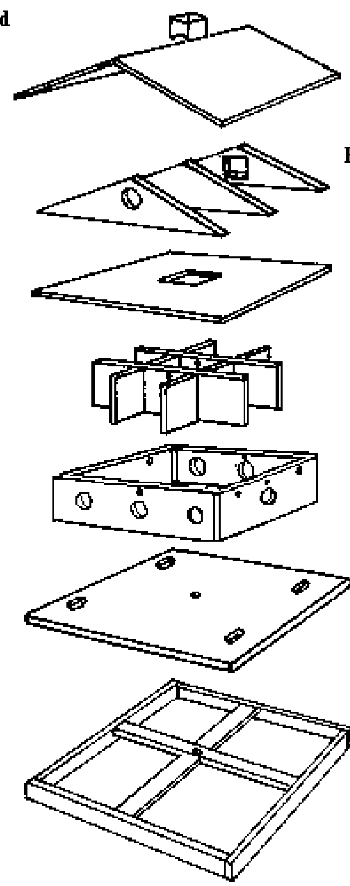
Note: This unit is held together by a threaded rod extending from the underside of the 1" x 2" base frame through the center of the chimney.

1. Mark all pieces on plywood sheet, then cut them out. Make four 1" x 1" x 5 7/8" corner blocks and eight 1" x 1" x 2" blocks to position the parts.
2. Cut out and assemble base from 1" x 2". Use 7d galvanized siding nails. Attach floor piece to base with glue and 1" or 1 1/4" nails.
3. Assemble the sides, alternating three hole and one hole pieces. Use glue and 1" nails or 3/4" #6 flat head wood screws. Use three at each end of each piece.
4. Position first-story sides on base piece. Mark position for each 1" x 1" x 2" block to hold side in position. Attach blocks to floor with glue and two 1" nails or 3/4" #6 flat head wood screws. Place completed sides in position on floor. Insert partitions. Position ceiling and mark for the location of 1" x 1" x 2" blocks near corners on the underside. Attach the blocks.
5. Place ceiling in position.
6. Glue pairs of end roof supports together to form gable ends 1/2" thick. Attach screen. Position and mark. Glue the two center roof supports together to make it 1/2" thick. It will be positioned adjacent to the threaded rod going up through the exact center of the house. Attach these pieces to the ceiling with glue and nails or flat head wood screws from the underside. Attach roof sides with glue and nails or screws.
7. Make chimney from a piece of 2x2. Cut V-notch on end to fit roof. Have it extend 2 1/2" above roof peak. Drill 1/4" hole in chimney and roof for rod. Nail chimney in place. Insert rod and tighten up.
8. Drill hole in top of pole to accommodate nut on lower end of threaded rod.
9. Use 1/2" diameter maple dowels to make a fence about 2" high on each balcony. Pieces of wood 1" x 1" x 3" may be used as the corner posts of this railing.

This pattern shows how to cut out a martin house from one sheet of plywood.



Layout pattern.



Expanded view of martin house. A threaded rod inserts through the base and up through the chimney.

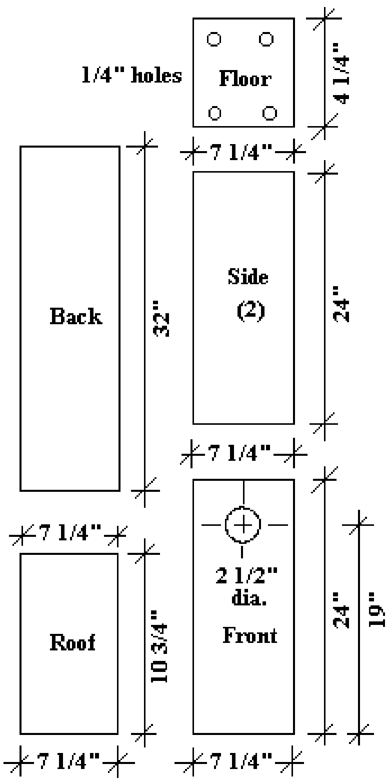
Entrance hole diameter: 2 1/4"

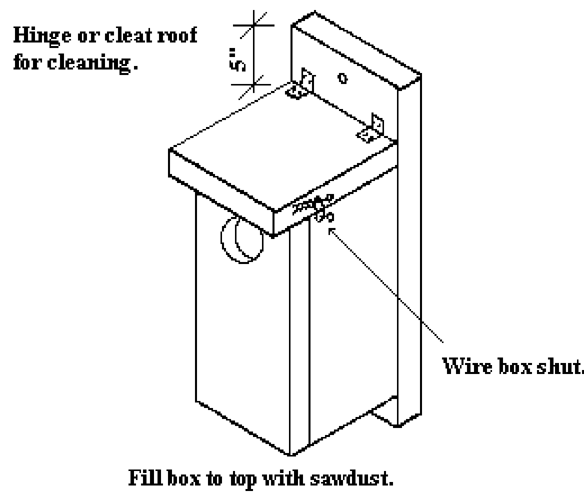
Locate 5/8" ventilation holes 1" below top edge of sides.

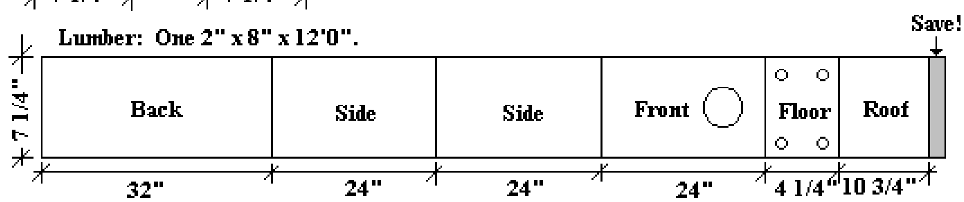
***For sides, measurement from floor to center of entrance holes = 2 1/8"**

Northern Flicker Nest Box

The flicker is a common woodpecker in North Dakota distinguished by its yellow tail feathers and red patch on the back of the head and neck. They nest in wooded areas and in town. Flickers are excavators and are more likely to use a nest box if it is completely filled and packed with sawdust. This simulates a dead tree with a rotting inside. Boxes should be attached to a post and placed 4-6 feet high. A 1 1/2" thick rough cut cedar material is preferred.

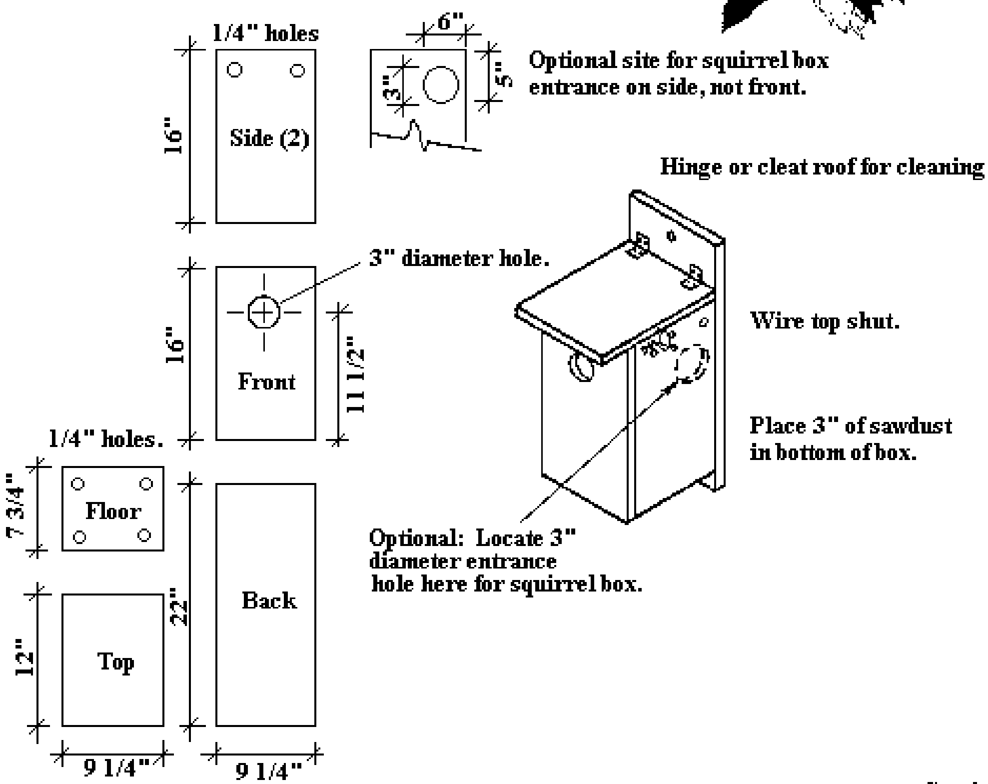


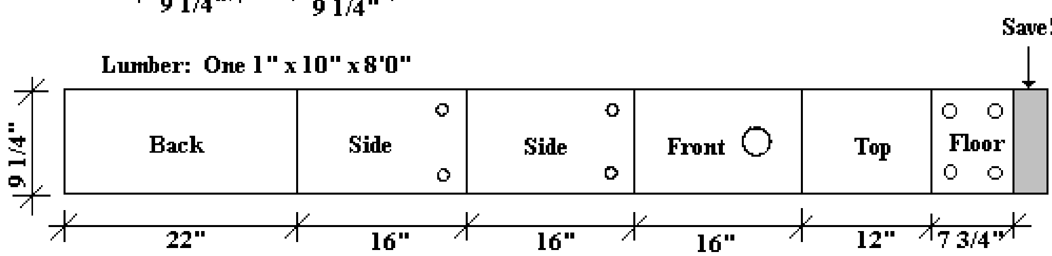




American Kestrel, Northern Screech-owl, Gray Squirrel, Red Squirrel, and Fox Squirrel Nest Box

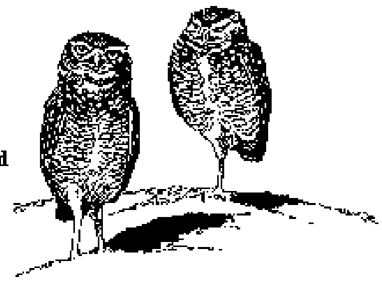
To attract kestrels, place the box in relatively open country on a tree or post 10-30 feet high with grassy habitat nearby. Screech-owls can be attracted along the edges of hardwood forests adjacent to fields or wetlands. Boxes should be placed at least 10 feet high. Both the kestrel and owl boxes should include a predator guard to keep squirrels from using the nest boxes. Squirrels can be attracted by using this box and filling it half full of leaves and mounting at least 30 feet above the ground on a tree at least 10 inches in diameter. It is not necessary to clean out squirrel boxes.





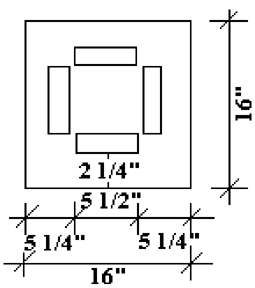
Burrowing Owl Nest Tunnel

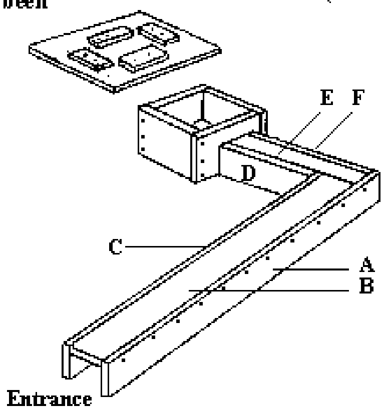
Burrowing owls were historically found throughout most of the mixed and short grass prairies of central and western North Dakota. They utilize burrows created by ground squirrels, prairie dogs, fox, coyote, and badger. Because of the loss of large tracts of native prairie to agricultural practices, much of the potential and stable burrowing habitat was also lost. The plans discussed below can be used to provide a nesting site on native prairie where natural burrows may not exist. Owls prefer areas with short grass where visibility is good. Dimensions below will be suitable for ungrazed pastures, however, 1 1/2" wood may be necessary in pastures where cattle or horses will be stepping on top of the structure. Bury the structure 6" below the surface. A mound of dirt built up around the entrance will simulate the mound of dirt around natural dens and aid in attracting owls. Success has been documented using this structure in western North Dakota.



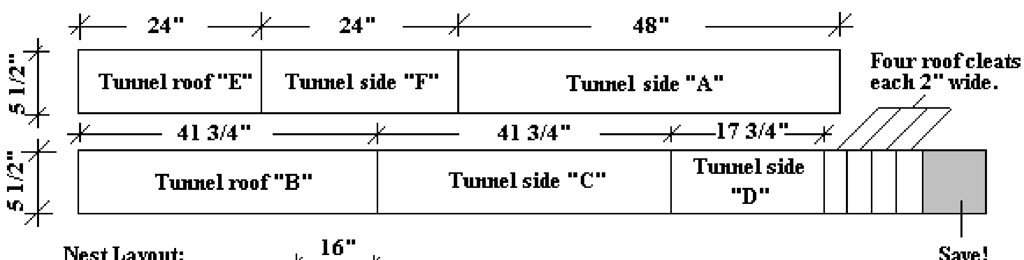
Removable roof. (shown upside down)

Bottom view of roof with roof cleats.

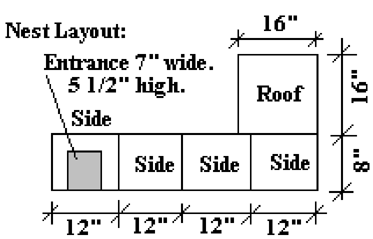




Lumber:
One 1" x 6" x 8'
One 1" x 6" x 10'
One piece of 1/2" exterior plywood 24" x 48"



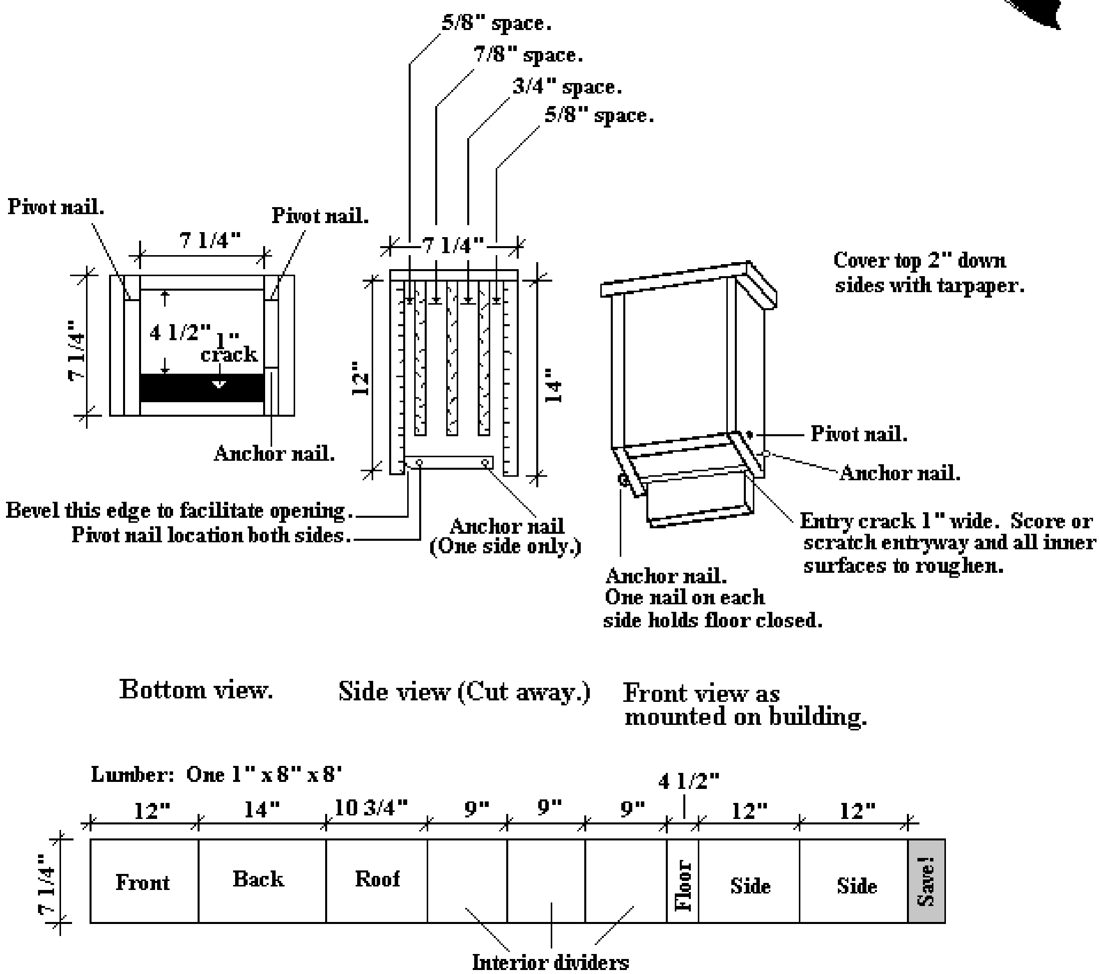
Nest Layout:



Select site on high, well-drained area. Bury nest box and tunnel 6" below ground surface. entrance should simulate a badger den entrance.

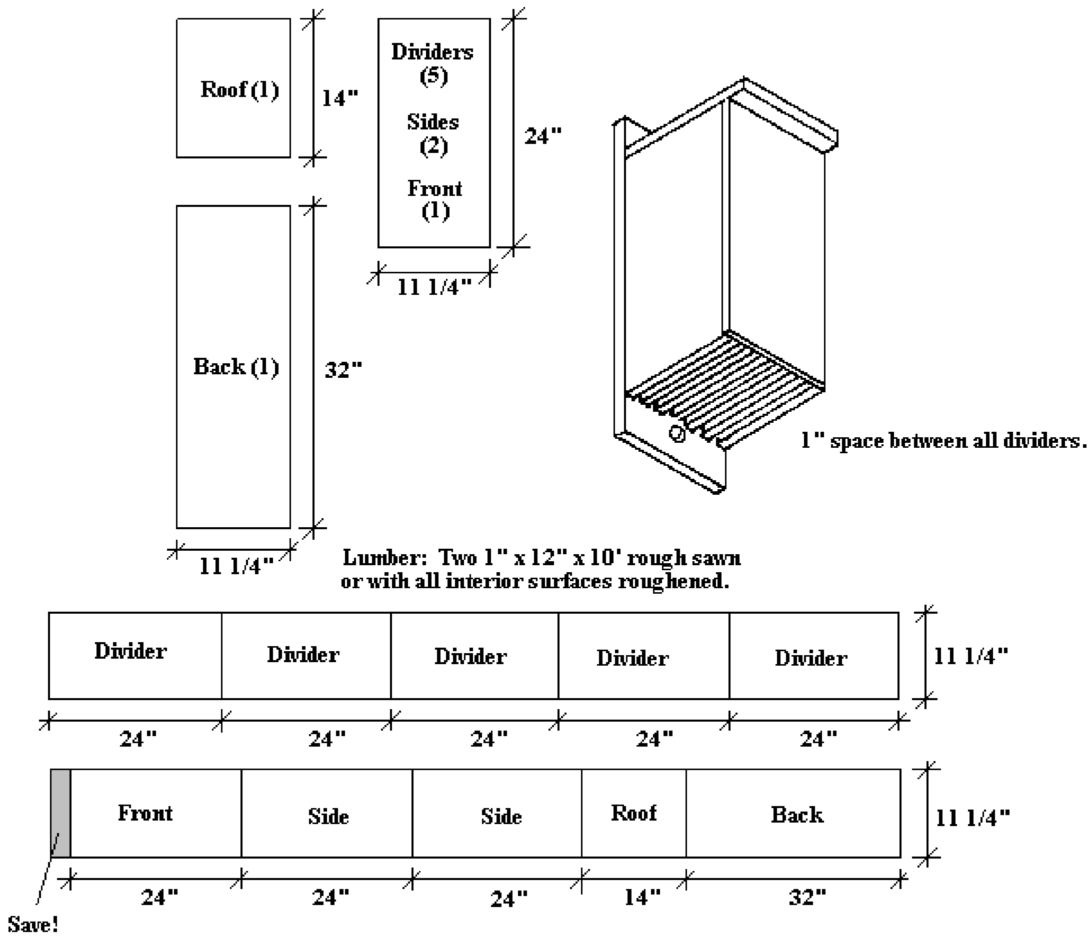
Small Bat House

Nine species of bats can be found in North Dakota but the little brown bat is the most common. Bats are insect eaters and may eat over 1,000 insects each evening. They require a warm, moist environment which reaches 80-90 degrees during the daytime. This can be achieved by covering part of the house with tarpaper Painting with black may also help. Houses should be hung on trees, poles, or the sides of buildings which have a good open area on at least one side for bats to maneuver while flying. The best habitat is close to rivers, lakes, or marshy areas where insect populations are high. Nest boxes should be about 12-15 feet above the ground.



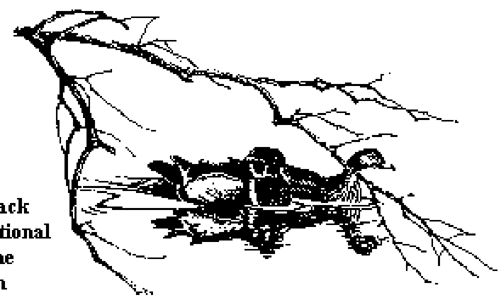
If you have success using a bat house, please contact our Department's Natural Resource Division.

Johnson Bat House

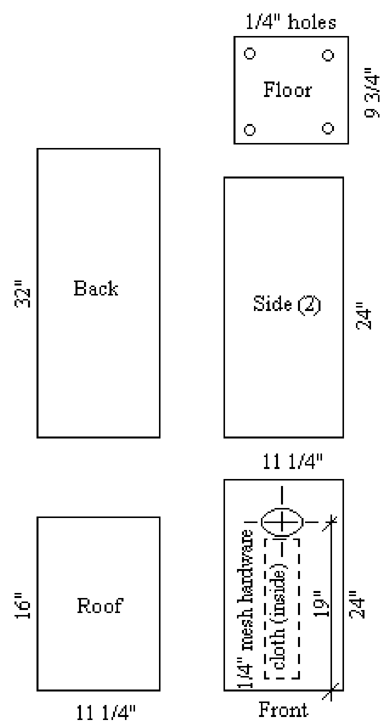


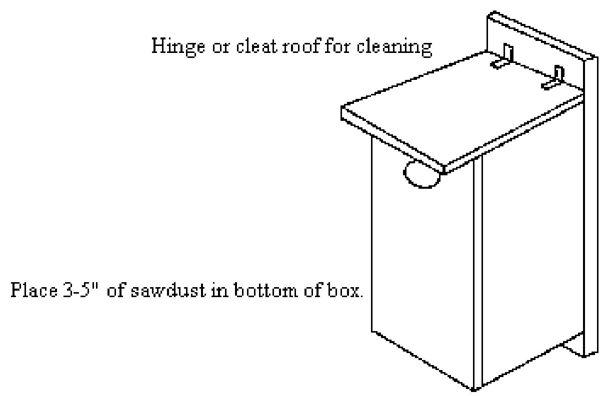
Note: All external seams and joints should be caulked if not tight fitting. Divider boards are spaced 1 inch apart.

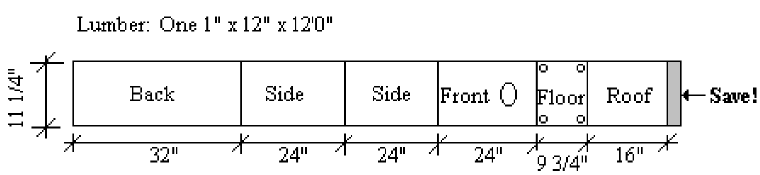
Wood Duck and Hooded Merganser Nest Box



Wood duck populations have made a significant come back during the past 20 years, in part because of adding additional cavity nesting habitat in the form of boxes such as the one described below. Boxes should be placed over water or in woodland habitat within one-half mile of a wetland. Since a female wood duck must lead her newborn young from the house to water, the path should be free of major man-made obstacles like street curbs, highways, or tightly woven wire fences. Boxes placed on posts over water should be 6-8 feet above the water's surface. Boxes placed in woodland habitat should be at least 20 feet high. At least 3 inches of mixed sawdust and wood chips should be put into the bottom of the box. The top of the box should be wired down to prevent raccoons from entering. It is important to attach a 1/4 inch wire mesh inside the box and below the hole so young ducklings are able to crawl out upon hatching. Entrance holes should be 3 inches high and 4 inches wide.

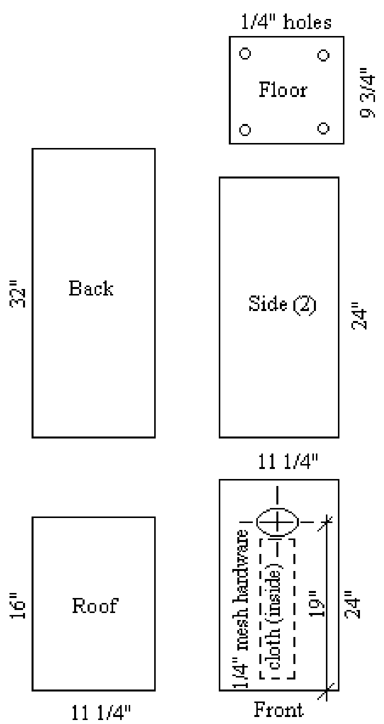




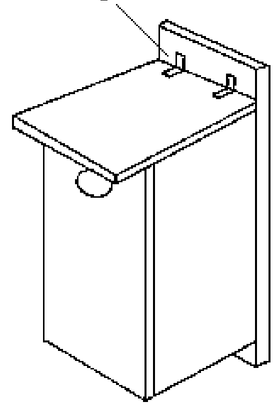


Raccoon and Common Merganser Nest Box

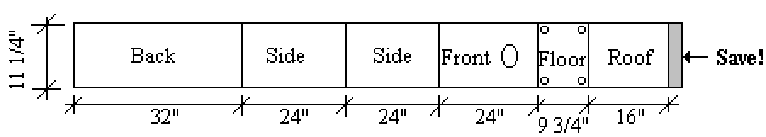
Pileated woodpecker 4" diameter round hole.
Hole sizes for common merganser and raccoon, see:
Entrance Hole sizes for Duck, Merganser, and Raccoon Nest Boxes



Fill box to top with sawdust for piliated woodpeckers.
For common mergansers, fill bottom of box with 3"-4" of sawdust.

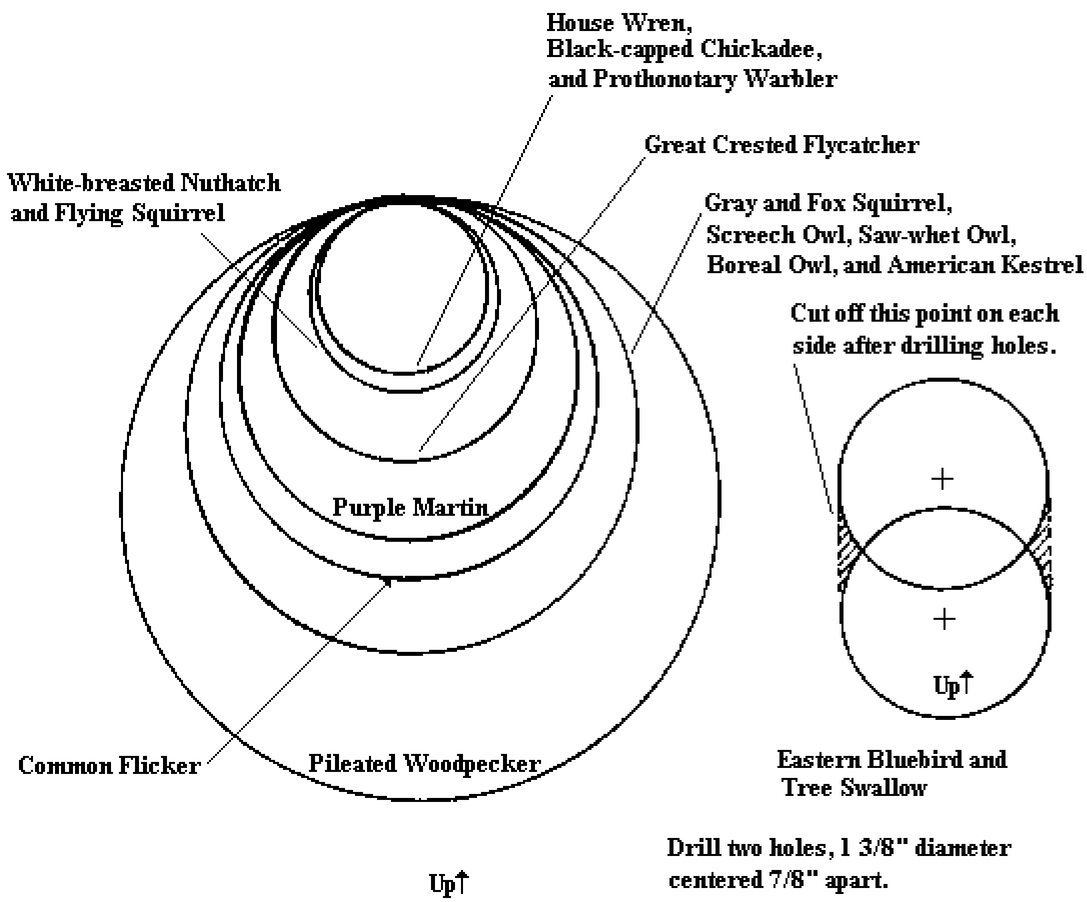


Lumber: One 1" x 12" x 12'0"



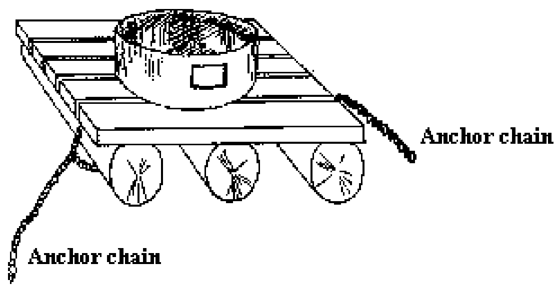
Entrance Hole Sizes for Songbird, Woodpecker, and Squirrel Nest Boxes (Actual size is shown)

Trace onto wood with carbon paper.

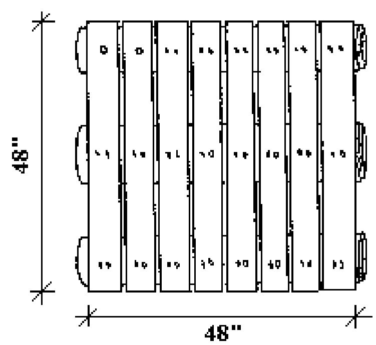


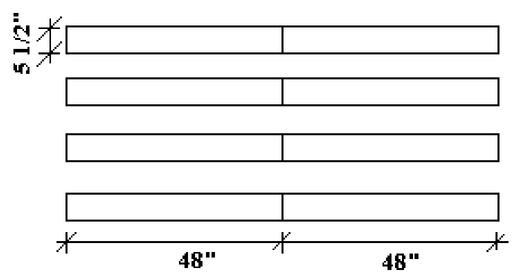
Canada Goose Nest Platform
Turtle and Duck Loafing Platform

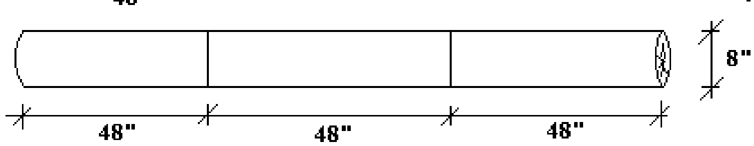
The giant Canada goose has made a tremendous comeback in North Dakota in the past 15 years. Part of this increase has been due to artificial nesting structures. There are various types of structures that will attract nesting including a floating structure described below. Cut the material as shown and nail boards onto pole sections. Attach a washtub or 10" high section of 55 gallon drum to the platform. Drill drain holes through bottom of tub and cut an escape hatch 6" wide and 4" high just under the top of the tub. This is for young geese to exit the tub. Paint the tub an earth tone color and fill 1/3 full with nesting material such as grass or hay. Anchor the platform in 2-4 feet of water. Nesting structures should be at least 200 yards apart if they are in view of one another. This will prevent territorial conflicts.



Materials:
One 8" diameter cedar pole - 12' long.
Four 2" x 6" x 8' boards.
One 22" diameter round metal washtub.
Do not use washtub for turtle and duck loafing platform.







Nest Tub

A structure which has also proven to be effective in attracting Canada geese is the fiberglass nest tub. These tubs measure 32 inches in diameter and have an 8" sidewall with an additional 2" drop in the bottom of the tub. These structures are mounted on a 9 foot pipe after the pipe has been driven into the bottom of the wetland. The best time to erect these structures is during the winter when you can work on top of the ice.

Select a location where the water will be from 1 to 3 feet deep and, if possible, at least 50 feet from the shore. A stand of emergent vegetation such as bulrush is an excellent location. The pipe should extend out of the water at least 3 feet. Choose an area along the north or west shore or in a protected bay where it will be less apt to get pushed over by the ice action in the spring. More than one structure can be placed in a wetland as long as they are at least 200 yards apart. It also helps if the view from one to the other is obstructed. Nesting material should be placed in the tub by March 1 as Canada geese are early nesters. Put enough material into the tub so that it extends above the top.

Geese will not always find the tub the first year--do not be discouraged. Check to make sure the tub is filled with nesting material annually and that the tub has not been pushed over by ice.

Fiberglass baskets (tubs) for elevated goose nesting structures:

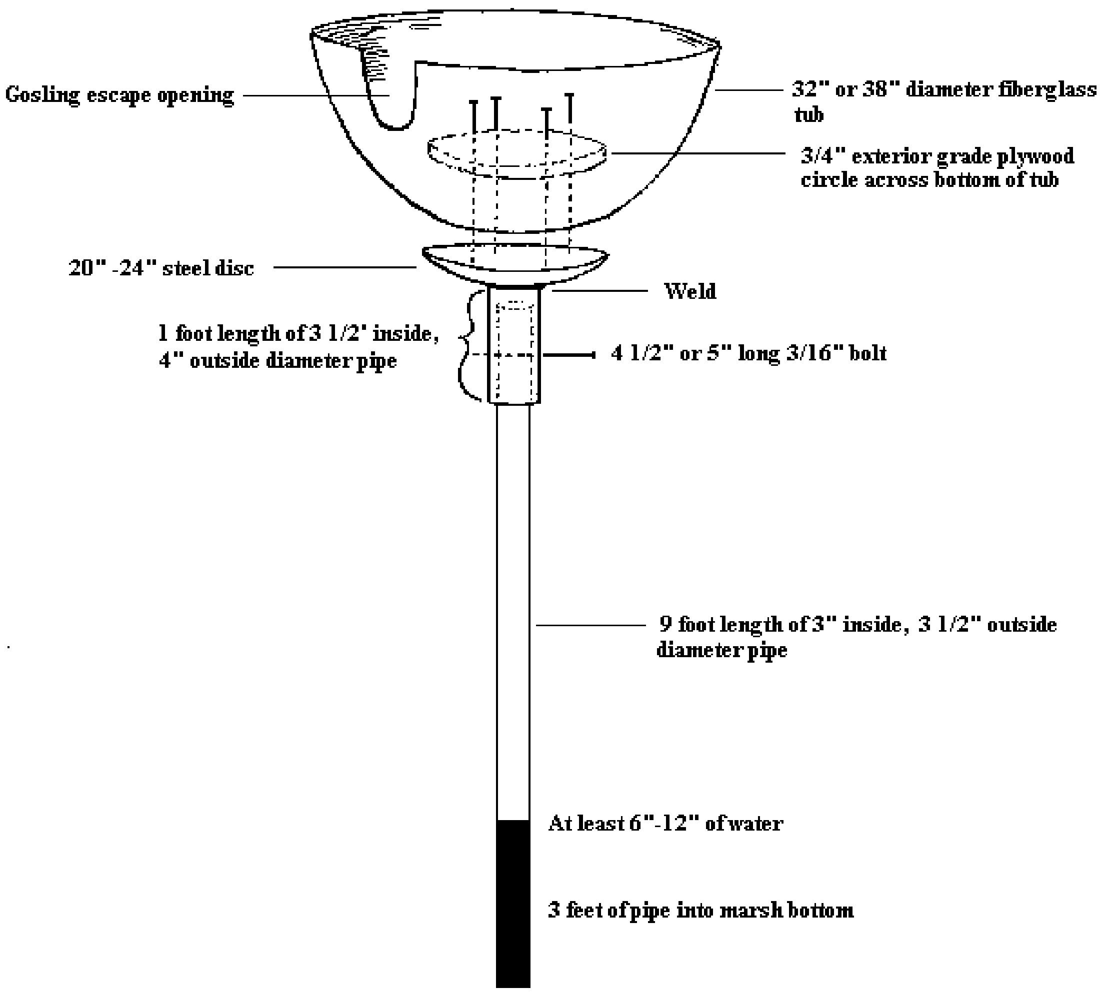
```
Fiberglass Unlimited, Inc.
South Highway 81
PO Box 1297
Watertown, South Dakota 57201-1297

Raven Industries, Inc.
Plastics Division
PO Box 1007
Souix Falls, South Dakota 57101-1007

Kenco Plastics Company, Inc.
State Highway 21
Necedah, Wisconsin 54646

Pleasure Products Manufacturing
2421 16th Avenue South
Moorhead, Minnesota 56560
```

Canada Goose Nest Tub



Culvert Nest Structure

A major downfall of most nest structures on private land has been that maintenance generally drops off with time. This causes structures like baskets to become useless, or even worse, death traps. Culverts, however, offer ideal nesting conditions and, if properly installed, require very little maintenance after the initial installation.

Fig. 2. Photo of culvert structure in a North Dakota wetland.

Location

Culverts are best suited for Type IV wetlands, followed by larger Type IIIs and sheltered areas of Type Vs. Culverts should be placed within six feet of emergent vegetation in a water depth of approximately 18 inches in the spring. One structure per 10 to 20 acres is a good goal and there should never be more than one per wetland acre. Areas with nearby trees should be avoided because they provide hunting perches for raptors and crows.

Installation

(Culverts of 1.5-1.8 m in height are preferable.) A culvert can be either installed in a dry wetland or through the ice. Installation in a dry wetland is much easier and less hazardous than through the ice. To install in a dry wetland, scrape a depression in the wetland bottom with a loader bucket. Using the bucket, push down and square the culvert in the depression. While installing through the ice, use good judgment as to what the ice conditions are. If ice is thick enough to support the equipment, start by cutting a hole in the ice. Cutting a hole in the middle of the circle of ice will make it easier to lift out. Once the ice is removed, push the culvert down into the mud and level it. Try to get the culvert into solid (but not frozen) bottom substrate.

Filling the Culvert

Culverts should be filled with soil suitable for plant growth. Rock or gravel are not acceptable fill material because they do not allow moisture to reach growing plants. The soil will settle and the culverts must be revisited to replenish the settled soil. The soil can settle as much as two feet, making it impossible for ducklings and goslings to escape. Filling the culvert with water saturated fill material may decrease the settling. Plan on revisiting the site(s) at least once and probably twice to replenish the settled soil.

Habitat/Cover

Culverts grow a variety of weeds from windblown or soil-stored sources. This is generally okay, but seed such as alfalfa, sweet clover, and native grasses could be spread into the soil to improve conditions. It generally takes 1 to 2 years before cover is adequate to attract nesting waterfowl. Nesting geese usually break down nearly all residual vegetation and use it as nest material. They also destroy the vertical and horizontal cover that attracts mallards. Generally geese and mallards will not occupy the same sight unless modifications are made. A partition may be placed into a larger culvert that separates geese and mallard nesting sights. The partition can be made from cedar boards (4 cm thick) to resist rot. Covering the partition with 15 cm mesh wire will allow mallards to squeeze through the mesh if necessary. A rounded opening of approximately 15 x 20 cm will provide access to the covered quadrants of the partition. Weaving 1-2 cm diameter willow sticks through the wire mesh on the side facing the open goose nesting area will ensure that the cover for the mallard nesting sight will not be incorporated into the goose nest.

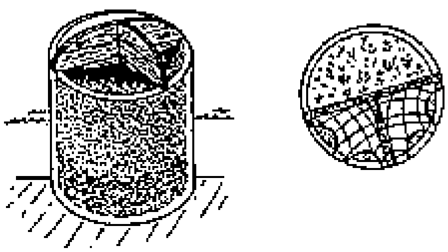
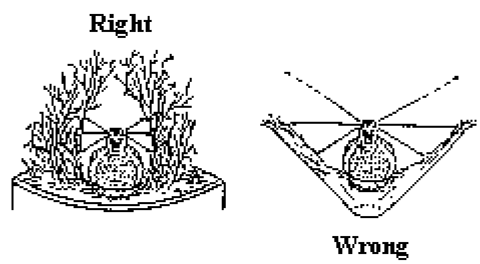
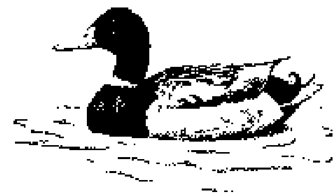


Fig. 1. Side and overhead view of culvert with mallard/goose partition.



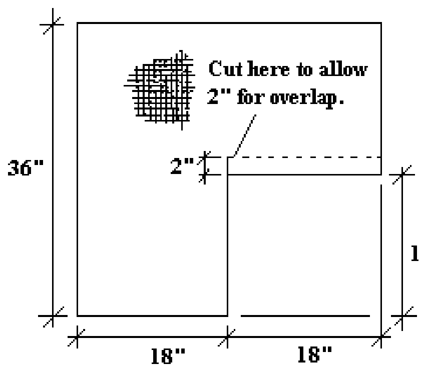
Mallard Nest Basket

This nest basket, similar to the design of a fiberglass goose tub, can be construceed to attract nesting mallards. The frame is made of 1/4" diameter steel rods mounted on 1" diameter steel support pipe. This pipe telescopes inside a 1 1/2" steel pipe with a set screw to establish the desired height. Baskets should be placed in wetlands where water is 2-4 feet deep and where water will remain until at least mid-summer. The basket should be at least 10 feet from shore and 3-5 feet above the water line. Baskets should be filled with flax straw or other suitable material and placed within areas containing some cattails or bulrush. It is easiest to place these nests during the winter, through the ice. They will need to be maintained annually before the nesting season.

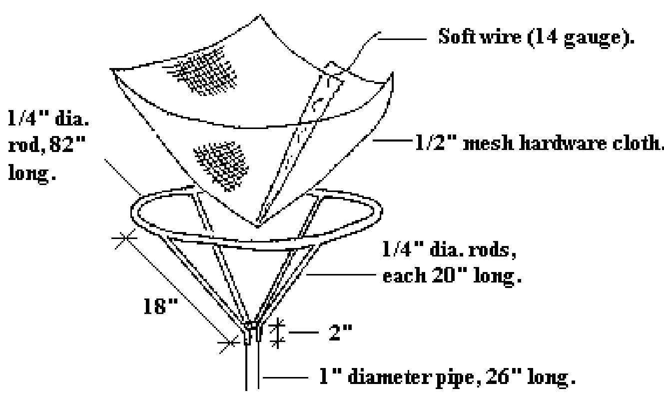


Materials:

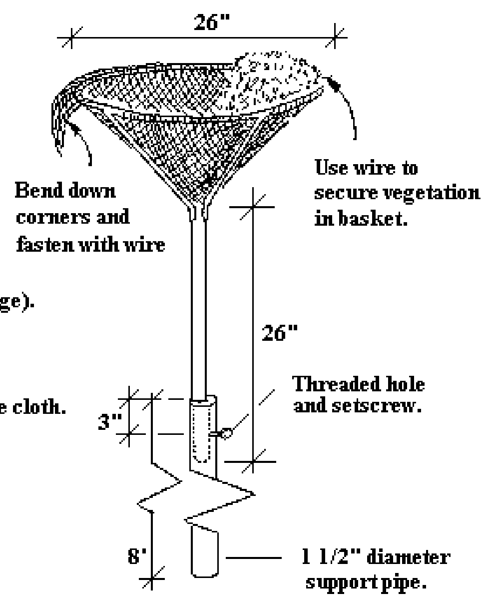
8' support pipe, 1 1/2" diameter.
2' 2" basket pipe, 1" diameter.
13' 6" steel rod, 1/4" diameter.
3' x 3' hardware cloth, 1/2" mesh.



Basket pattern.



Nest basket.



Frame and basket assembly.

Hen House

The basic design of the hen house is a three foot long grass cylinder. The hen house is easy to build and all the materials are readily available.

Materials to build a hen house include:

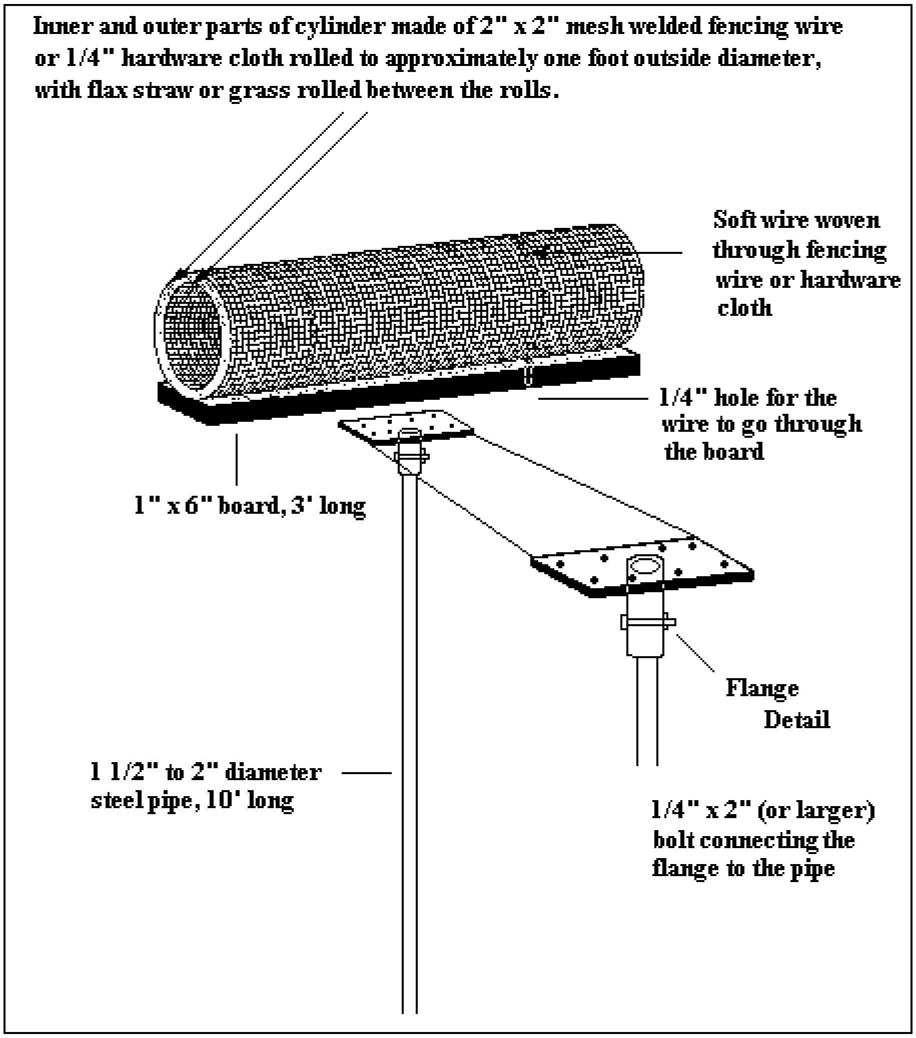
- 7 foot piece of 2" x 2" mesh welded fencing wire 36" wide or 1/4" hardware cloth
- 1" x 6" x 3' treated lumber
- 10 foot long 2" pipe
- wire
- four screws
- pipe flange
- flax, marsh grass

To make the cylinder, cover one-half of the fencing wire with an inch of grass and roll it into a foot diameter cylinder.

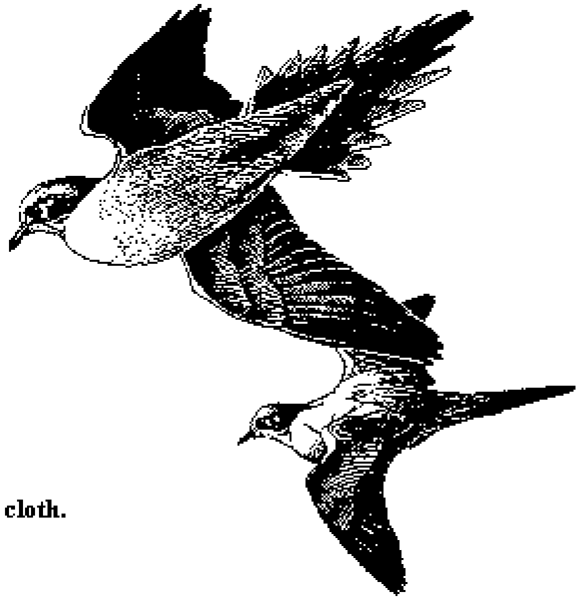
Take short pieces of wire and tie the roll together in two or three areas. Use screws to attach the flange onto the center of the board.

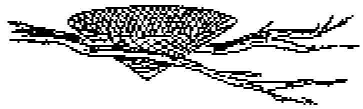
Attach the cylinder to the board with pieces of wire about five feet long, weaving the wire through the cylinder and attaching it to the board. Repeat this two or three times to make sure the cylinder is on tight.

Pound the 10 foot pipe into the bottom of the wetland to make sure the pipe is stable and secure. About three feet of pipe should be left out of the water. The nest is then attached to the pipe with a flange. Installation of nests should be done in late winter when pounding the pipe into the wetland bottom and attaching the nest can be done easily. Hen houses should be placed at least 100 feet apart because hens are territorial and are intolerant of other ducks nesting in close proximity.

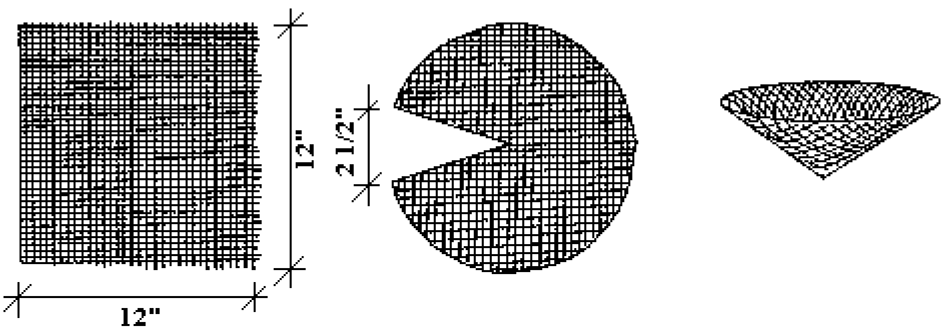

Inner and outer parts of cylinder made of 2" x 2" mesh welded fencing wire
or 1/4" hardware cloth rolled to approximately one foot outside diameter,
with flax straw or grass rolled between the rolls.
Soft wire woven through fencing wire or hardware cloth
1/4" hole for the wire to go through the board
1" x 6" board, 3' long
Flange Detail
1 1/2" to 2" diameter steel pipe, 10' long
1/4" x 2" (or larger) bolt connecting the flange to the pipe

Mourning Dove Nest Basket





Materials: One 12" x 12" piece of hardware cloth.

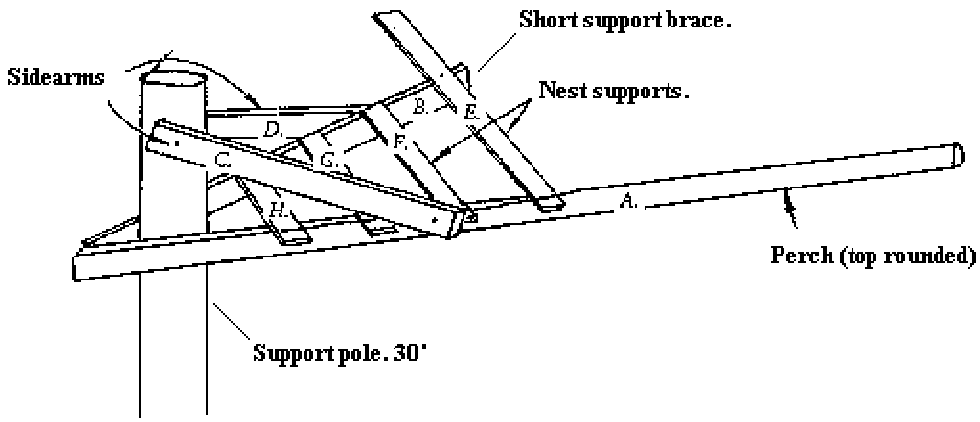


Cut with tin snips to form a circle. Cut out a narrow pie-shape and wire edges together to form a cone. Wire and/or staple cone into the crotch of a tree limb.

Great Blue Heron Nest Platform

The great blue heron is an elegant water bird found throughout North Dakota. It is most commonly found nesting near rivers, lakes, or other water bodies that contain live mature or dead trees. Here, herons construct a nest of sticks at least 20 feet high. They nest in colonies, meaning there are many heron nests within one small area. Nest platforms should be used in the vicinity of a present colony or to enhance an existing one where trees are deteriorating.

Support poles should be 30 feet high and 6-8 inches in diameter. Three nest platforms can be placed on each pole. The first is at the top and the other two staggered at 180^0 and 4 feet intervals. Placement of heron platforms is best conducted through the ice from January through March.



Lag screws should be used to attach platform to pole.

Position sidearms on support pole so nest is inclined upward at approximately 7degree angle.

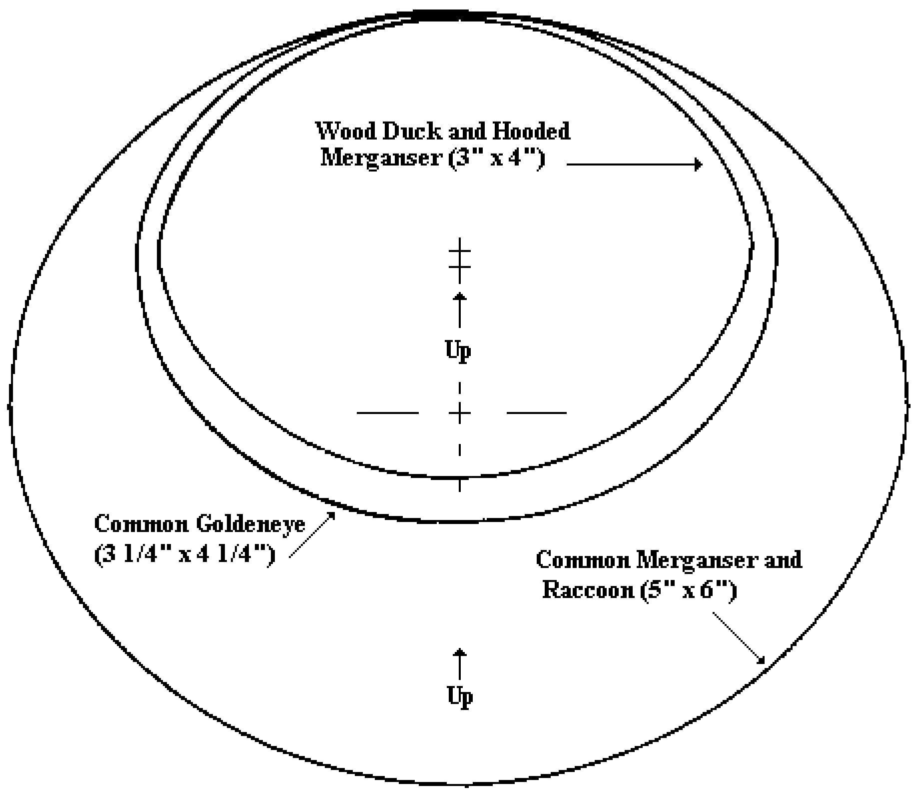
Wire armful of sticks on lath nest supports to stimulate use.

Lumber:
A. 2"x 2"x 7'.
B. 2" x 2" x 30".
C. 1"x 2"x 26 1/2".
D. 1" x 2" x 26 1/2".
E. 1"x 2"x 39".
F. 1"x 2"x 19 1/2".
G. 1" x 2" x 19 1/4".
H. 1" x 2" x 17 7/8".

One 30' cedar support pole/three platforms.

Entrance Hole Sizes for Duck, Merganser, and Raccoon Nest Boxes (Actual size is shown)

Trace onto wood with carbon paper.



Feeders

General Information for Wildlife Feeders

Feeding birds can provide entertainment and enjoyment for people of all ages. You can attract birds to your backyard throughout the year but the most important time to help the birds is during the winter. Cold temperatures and snow limit the food available and put extra demands on birds to keep warm. In the spring and summer, birds feed on insects which are plentiful. Feeding should be restricted to feeders and not simply thrown on the ground.

Once you begin feeding during the winter, don't stop. Birds become dependent on a food source and may not locate an alternative once you stop feeding. There are a variety of seeds and foods that attract birds. The development of black oil sunflower seeds revolutionized bird feeding. It is the single favorite and most nutritious food for birds. Adding specialty foods to feeders will attract even a wider variety of birds. In the summer, for example, sugar water attracts hummingbirds. Fruit brings northern orioles, waxwings, blue jays, and thrashers. Meal worms can lure in bluebirds. In the spring and fall, thistle seed will attract the Harris' sparrow and red-breasted nuthatch. A mixture of black sunflower and thistle attracts evening grosbeaks, red polls, and pine siskens during the winter. Niger thistle attracts purple, house, and goldfinches all year long. Suet will be utilized regularly by woodpeckers, nuthatches, and chickadees.

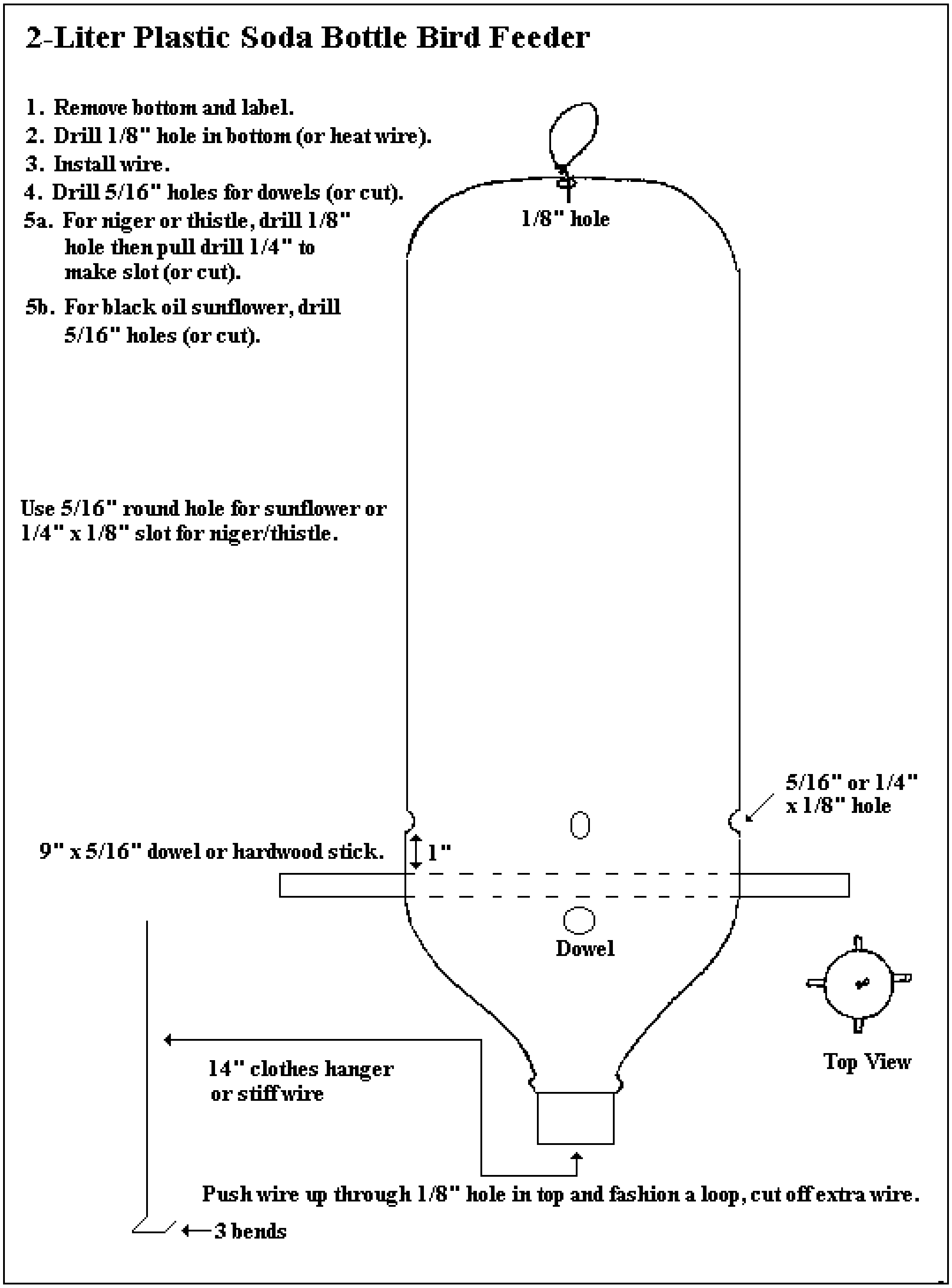
Placement of your feeder is as important as what feed you put in it. First, consider where you want to watch your birds. Is it by a window, on a glass door, or on the second story? Pick a location that is easily accessible for filling with food and out of the wind. Also consider the mess that empty and spilled seeds will cause below the feeder. Finally, keeping unwanted predators such as stray cats away from your feeder is important. Cats kill millions of songbirds annually and should be prevented from climbing near feeders. Locate your feeder at least 4-5 feet away,from overhanging tree limbs, fencing, or other structures.

This practice may also prevent squirrels from climbing on the feeder. The addition of a predator guard on the support pole may also prevent unwanted visitors. If squirrels still persist at a feeder, lure them to the other side of the yard with an easily accessible tray of peanuts.

Check your feeder for cleanliness if you use a tray or platform type. A dirty feeder may cause disease or discourage birds from coming. If you have trouble attracting birds, try adding a water source. Local bird populations will fluctuate, however, and birds absent for a period of time should not concern you.

Added attractions to your backyard can be lured in with additional types of feeders. The barrel type feeder described is excellent for attracting deer, turkey, pheasants, and cottontail rabbits if filled with corn, sunflower, and oats. You may also attract wood ducks or other waterfowl if you are located in the appropriate area.

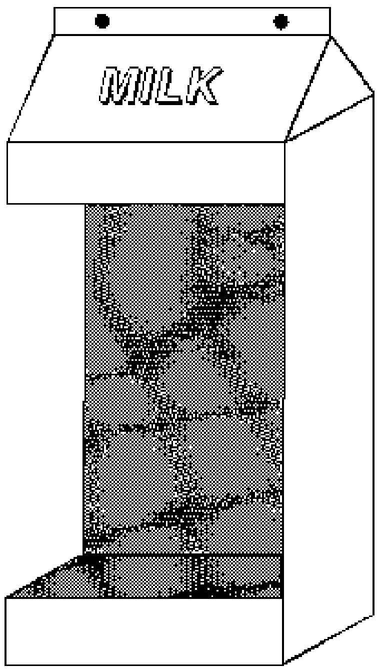
2-Liter Plastic Soda Bottle Bird Feeder



Milk Carton Feeder

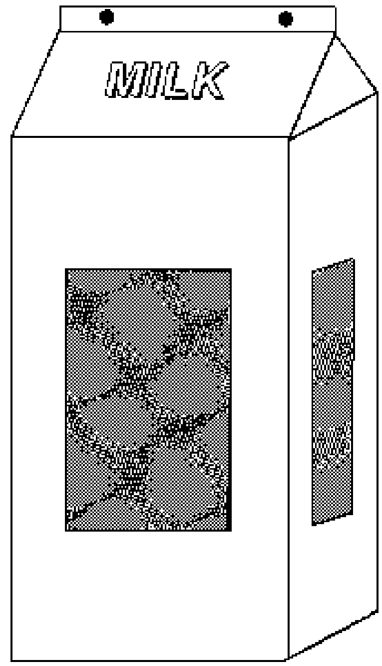
by Alice J. Turner

Feeder A



Empty one-half gallon milk cartons can be turned into a variety of bird-related items. To make a bird feeder, you can cut away two adjoining sides of a carton, leaving two inches at the top and bottom. You will have two solid sides (see Feeder A). Another plan is to cut windows in all four sides of the carton, again leaving about two inches at the bottom (see Feeder B).

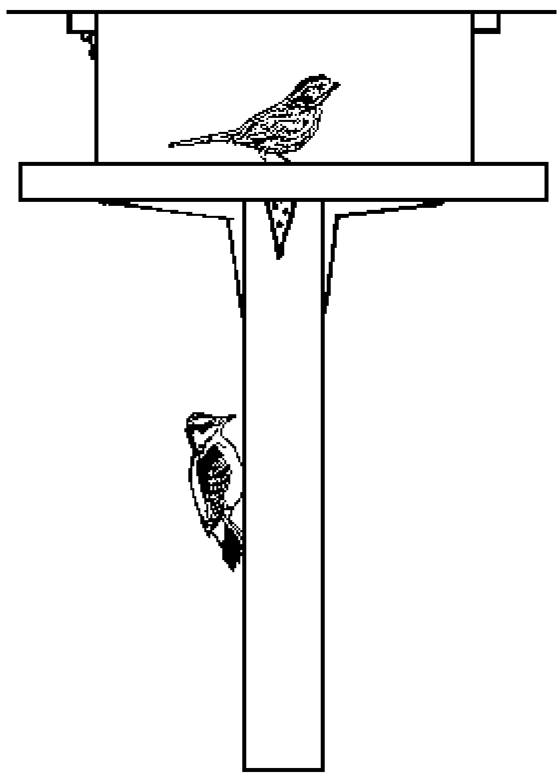
Next punch two holes in the top of the carton. Thread some strong string through the holes and tie it, making a loop for hanging. Now you can put the feeder wherever you want. Both of these designs can also be used as bird baths.



Feeder B

Large Self-Feeder

Ensure all necessary parts and tools are present. (Refer to Figure 1 and hardware list below.)



- 2 long brackets
- 2 short brackets
- 12 - 1" x 3/16" bolt/washer/nut assembly
- 2 - 3" hinges
- 2 latch hook assembly
- 48 - 1 5/8" galvanized drywall screws
- 34 -1" galvanized drywall screws

Attach two roof stops to bottom of roof using three 1" screws per roof stop. Screws should be driven from top of roof (refer to Figure 3A).

Attach two side rails to two end rails forming a rectangle of 1 by 2s. 1 5/8" screws should be driven into side rails which overlap the end rails. Attach this rectangle of 1 by 2s to plywood floor with 1 5/8" screws driven in from plywood side (see Figure 3B). This railing will hold seed on the platform.

Assemble body of feeder utilizing two 2 x 12 x 12 1/2" ends and two 12 x 26" sides. Attach 12" plywood sides to the longer (12 1/2") length of the end pieces with four 1". screws. The 1/2" gap remaining at the bottom of the rectangular box will function to release seeds from the body of the feeder (refer to Figure 3C).

Center body of feeder on top of floor and attach from bottom of floor with 1 5/8" screws. Screws should come up through plywood and into the 2 x 12" ends.

Drill at least six 1/4" drain holes into floor of feeder platform.

Place roof assembly on the ground with roof stops facing upward. Turn body of floor assembly upside down, grasp the floor, and insert body of feeder between roof stops. (Body of feeder should fit snugly between roof stops.) Attach two hinges to one roof stop and two latch hooks to other roof stop. Attach hinges and latch hooks to body of feeder. Use 1" screws to attach hinges (refer to Figure 3D).

With roof latched and top of roof on the ground, center 4 x 4 post on bottom of floor and mark with pencil. Position brackets using pencil outline of 4 x 4 post. Mark and drill bracket holes through plywood and attach brackets with l" x 3/16" bolts, tighten. Place 4 x 4 post into position and fasten using 15/8 screws. (Disregard this step if you plan to move the feeder to its final location in two pieces.)

Optional: Add a center peak structure as illustrated by the dashed line in Figure 3E. Two pieces of either 1/2" plywood or pine should be cut 26" long and approximately 5" wide. Nail or screw together to form a 45 degree angle and fasten to the center of the floor of the feeder body. (This structure prevents old seed from accumulating in the center of the seed reservoir and increases efficiency of seed dispersal.)

To erect feeder, dig a hole approximately two feet deep. Place post in hole and keep straight while occasionally packing dirt as hole is filled. IMPORTANT NOTE: Feeders must be coated with a good exterior paint for long life and weather proofing. This may be done before or after putting the feeder up. However, the portion of the post being buried should be painted unless lumber is pre-treated.

Additional: Figure 2 demonstrates how to get the necessary plywood pieces to construct two large winter bird feeders from one sheet of plywood. (The cost of approximately $9 per feeder for plywood and a $6 charge per 4 x 4 post demonstrates that the material to build this feeder can be purchased for under $25.)

TOOLS REQUIRED

- Table saw
- Philips head screwdriver
- Wrench to tighten bolt assemblies
- Standard screwdriver
- Paint brush/paint
- Post hole digger

Figure 1. Wood required to assemble one Large Winter Bird Feeder

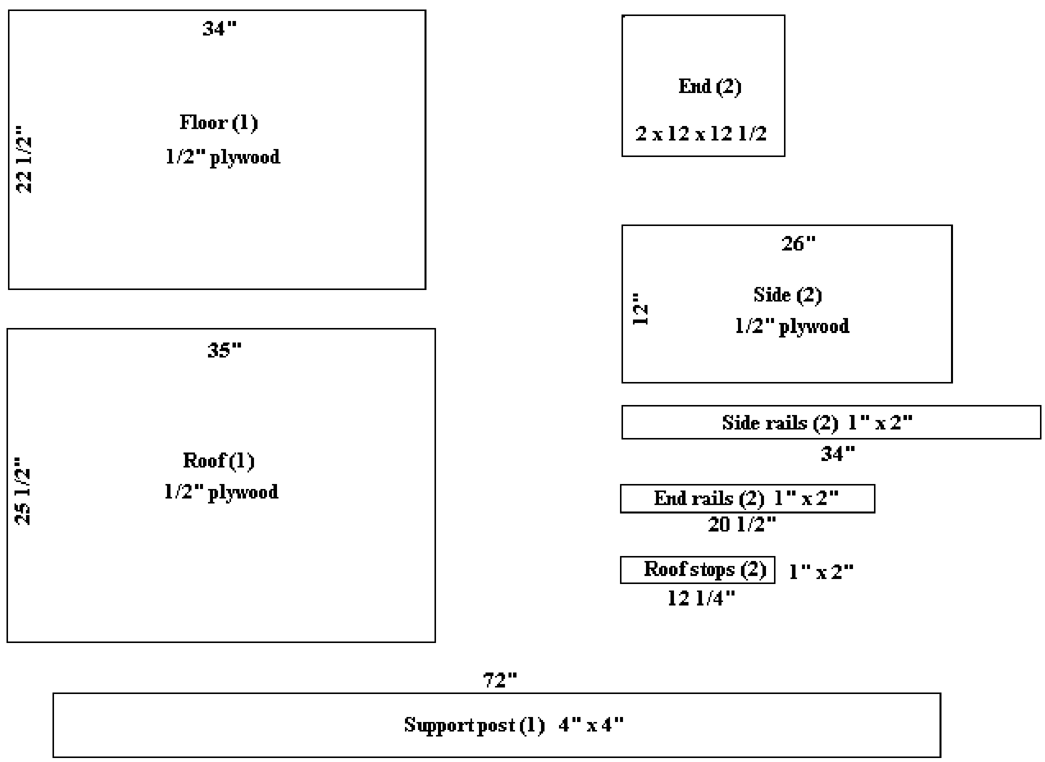


Figure 2. Utilization of one 4' x 8' x 1/2" CDX PLYWOOD to make two Large Winter Bird Feeders

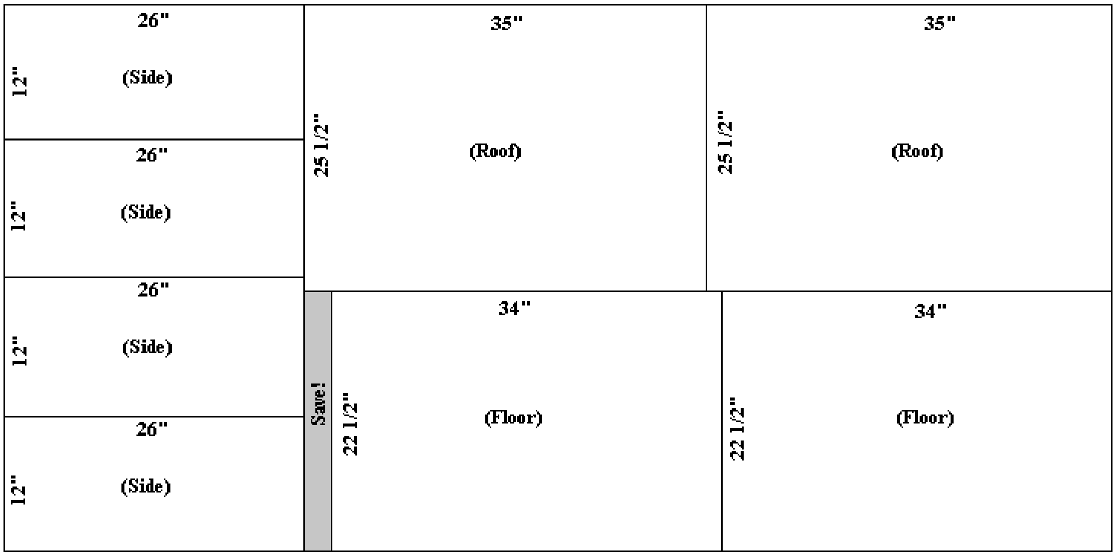
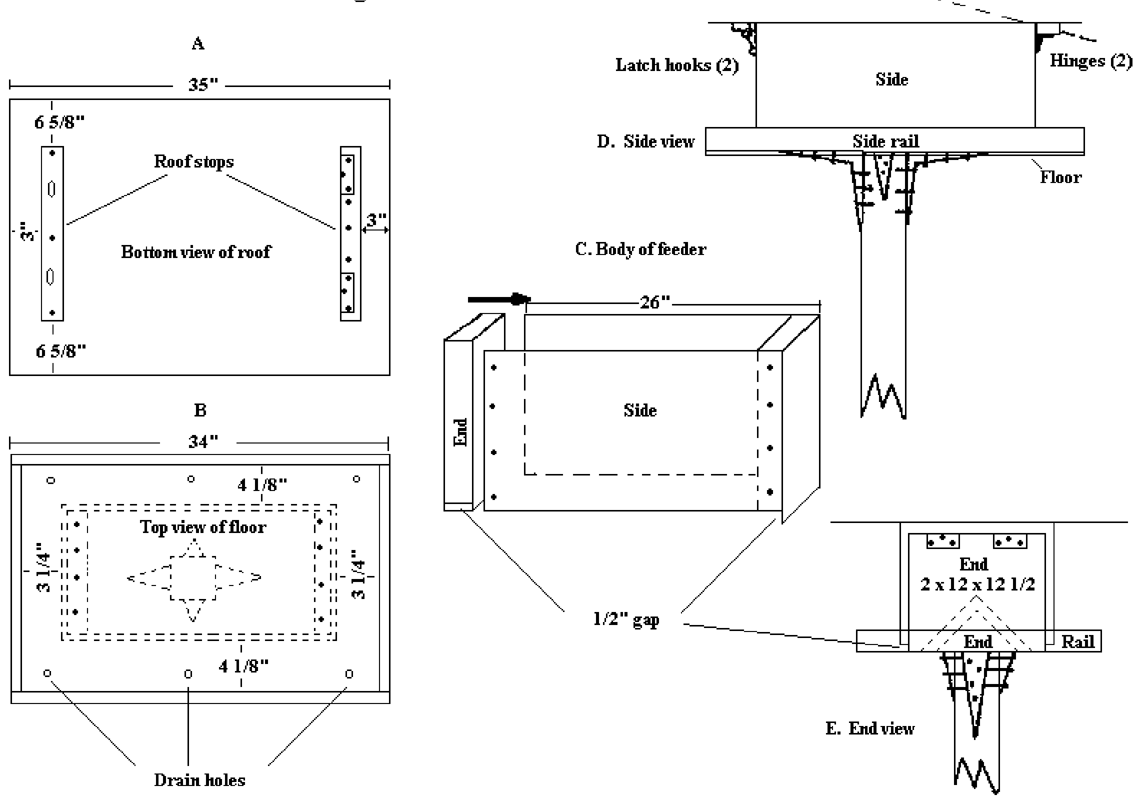
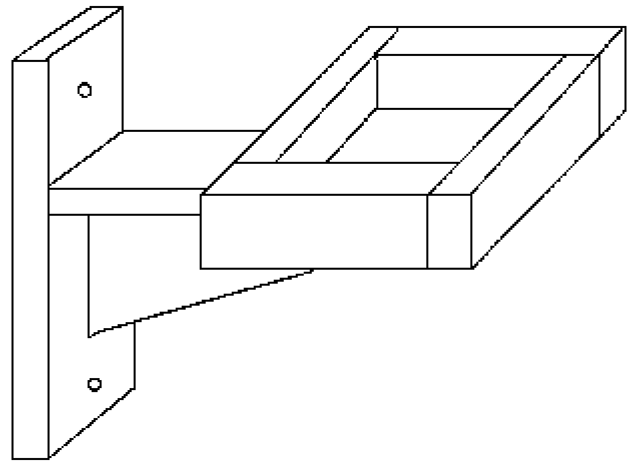


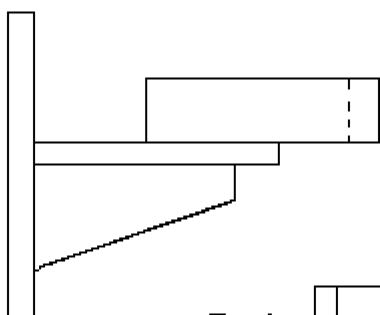
FIGURE 3. Construction diagrams



Linda Tray Feeder

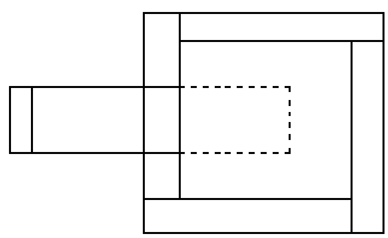
Materials: 1" x 6" - 39 1/2"

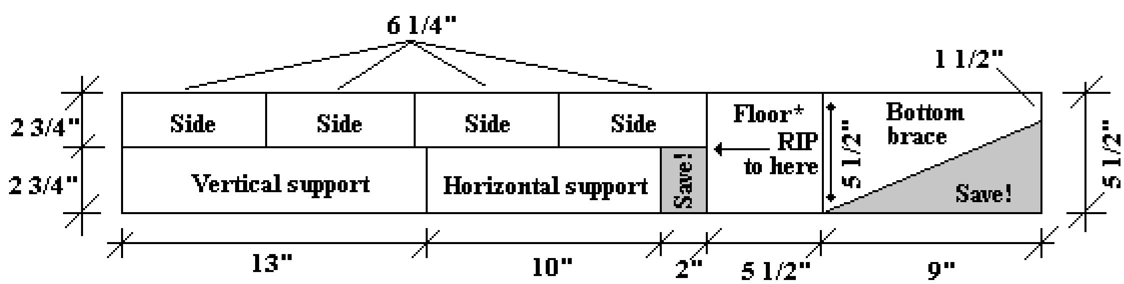




Side view

Top view



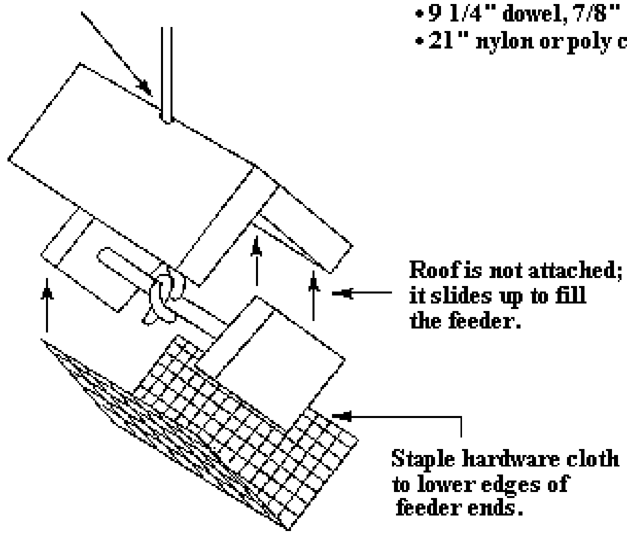


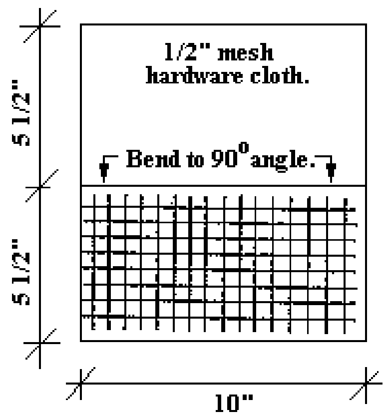
*If the board is 3/4" thick, the floor must be 5 1/2" x 5 1/2".
If the board is 7/8" thick, the floor must be 5 1/4" x 5 1/4".

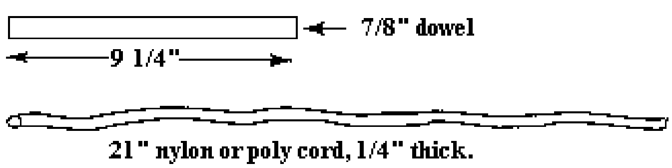
Hardware Cloth Suet Feeder

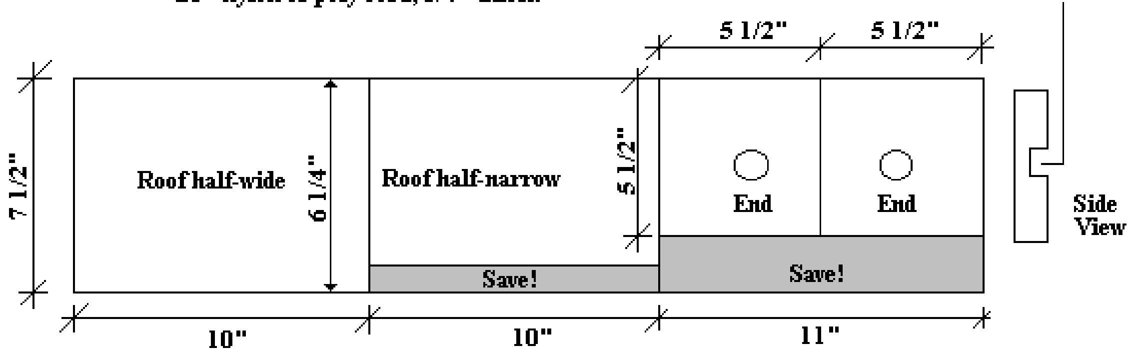
Materials:

- 11" x 10" hardware cloth (1/2" x 1/2" mesh)
- 1" x 8" - 32" (allow 1" for saw kerfs)
- 9 1/4" dowel, 7/8" diameter
- 21" nylon or poly cord

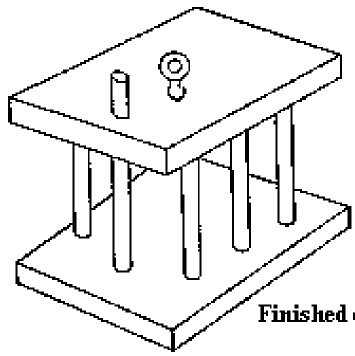




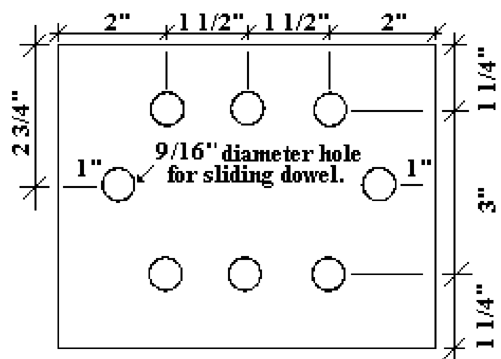


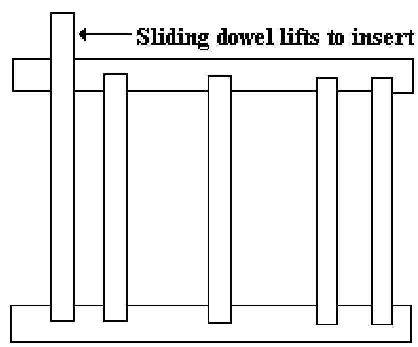


Dowel Suet Feeder

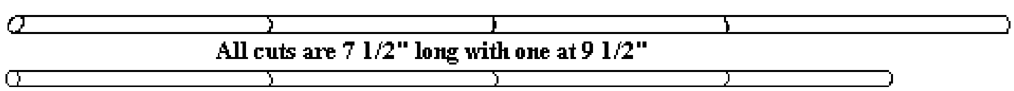


Finished dowel suet feeder.

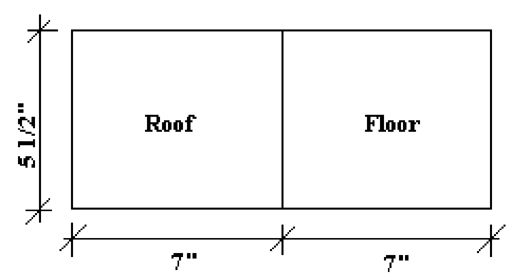




This diagram shows placement of dowel holes on the top and bottom pieces. Holes are 1/2" diameter and 1/2" deep, except that the floor hole for the sliding dowel is 1/2" deep, but the sliding dowel penetrates the roof and is lifted to insert suet.



1/2" diameter dowels.



Materials:

- wood glue
- 1" x 6" - 14"
- 2 - 1/2" x 36 " dowels
- eye screw (3/4" long)

Barrel Feeder for Wildlife

A simple feeder can be constructed from a 55 or 30 gallon steel barrel which can often be acquired for little or no cost. This type of feeder can be filled with any grain including black oil sunflower, corn, oats, or a mixture of grains. It serves as a ground feeder and is excellent for deer, turkeys, and other upland birds.

Instructions

Find a barrel which did not contain pesticides or other toxic chemicals. The barrels most commonly available are those which contained petroleum products. Ensure any residue is washed from the inside of such barrels.

Remove one end of the barrel. This will become the top end into which grain is poured. **Do not** attempt cutting out the end with a cutting torch as vapors within the barrel may be explosive. Instead, use a saber saw with a metal cutting blade or a large hammer and metal cutting chisel.

Make a 12 inch cut lengthwise along the bottom edge of the barrel about 2 inches above the bottom base ring. The cut should be started by first drilling a 3/8 inch hole where the cut will begin. Cut 12 inches across the bottom beginning at the 3/8 inch hole with a saber saw and fine metal cutting blade.

Pound in the metal above the 12 inch cut. The result should be a half-moon shaped opening that will release grain as it is taken from the small tray opening below.

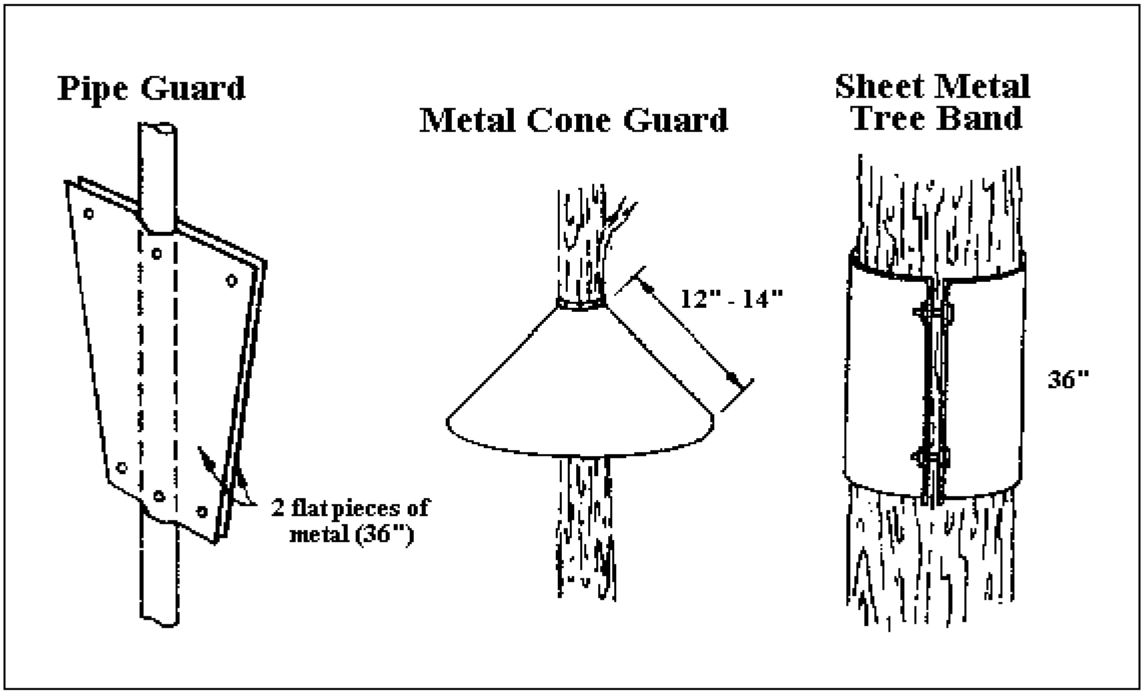
If the barrel did not come with a lid, cut a section of exterior plywood slightly larger than the opening in the top of the barrel. Secure this lid to the barrel using tarp straps. Eye bolts can be fastened to both the barrel and the plywood for points to hook the straps. As an alternate and more simple method, nail three small blocks of wood on the bottom side of the lid just inside the top edge of the barrel and place a brick or other heavy object on top to hold the lid in place.

Predator Guards

"Predator proofing" is an important aspect to consider during the construction phase of bird nest boxes or feeders. This simple step can prevent unwanted predators from destroying eggs or young in a nest box and make your feeder more attractive for wary birds.

All of the predator guards shown below serve the same purpose--to keep predators such as house cats, raccoons, and snakes from scaling the support post to your nest box or feeder. Wood posts are the easiest for predators to climb because they provide a rough surface with a good grip. Metal pipes or posts are less likely to be climbed successfully.

Materials to build predator guards can be made from tin, sheet metal, aluminum, or heavy plastic. A good source of cheap sheeting is often a newspaper office. Aluminum sheets are used to make the impression to print the newspaper and are recycled afterwards.



Wildlife Viewing and Photography Blinds

Viewing or photographing wildlife is made easier if you are stationary and let the wildlife come to you. It is easy to attest to that if you've ever fed birds in your back yard at a feeding station. The same approach should be used if you travel out-of-doors to view or photograph wildlife. The fact is that wildlife subjects are just that--wild, and normally won't allow you to approach closely. A little more time will be required to construct, place, and maintain a blind, but the time involved will be far less than the time spent in frustrating pursuit of wary wildlife.

There are as many types and shapes of blinds as there are inventive minds who build them. The main point is that the blind be large enough to make you comfortable, made of dark canvas so light cannot penetrate, and allow your shadow to be seen, made sturdy and anchored to the ground to prevent it from blowing away, and placed in the correct habitat and camouflaged to maximize your chances of seeing wildlife.

Choosing the correct habitat to place the blind is easier and more effective if you know your subjects' habitat and characteristics. Viewing deer, for instance, would require that a blind is placed near a food source where the deer is feeding in the evening, or on a trail that leads from where it feeds to a bedding area where it rets during the day. Another possibility would be a blind near a trail of rubbed trees where a buck frequents in the fall or an area where deer congregate to winter. Every species of wildlife act relatively the same from day to day or season to season and a pattern can usually be established if you do your research.

Other useful tips that may enhance your success include pre-positioning a blind for some time before you plan to use it. Time for the wildlife to get used to the presence of the blind is important. The blind should also be positioned so that the prevailing winds blow from the subject to your blind and not toward the wildlife. Birds are not of concern with this issue. Movement within the blind should be minimal and loud talking prohibited. Bringing a stool or short chair will make the stay more comfortable as patience is often a virtue when sitting in a blind.

Low-Profile A-Frame Blind

Materials Required:

- 4 - 6 (2x2)
- 4 - 2 1/2' (2x2)
- 4 small screws
- 3' of small chain
- 3 - hinges 2" x 3" (with screws)
- Staple gun and 5/8" staples
- 10' x 5' dark canvas
- Carpet knife
- 8 - 2 1/2" wood screws
- Wood glue (optional)

Cut 2x2 material into four 6' lengths and four 2 1/2' lengths. Miter each end with a 45° cut.

Put together with wood screws and glue (for added strength) two rectangular halves each the same size. Let dry.

Add 3 hinges along top edge of blind so halves will fold together like a closed book.

Use a second person to hold halves open to the desired height you wish blind to maintain during use. (The desired angle would likely be close to 90 degrees.) Pick a point half way between the top and bottom of the blind. Use small screws to attach a length of chain to keep blind open in desired position.

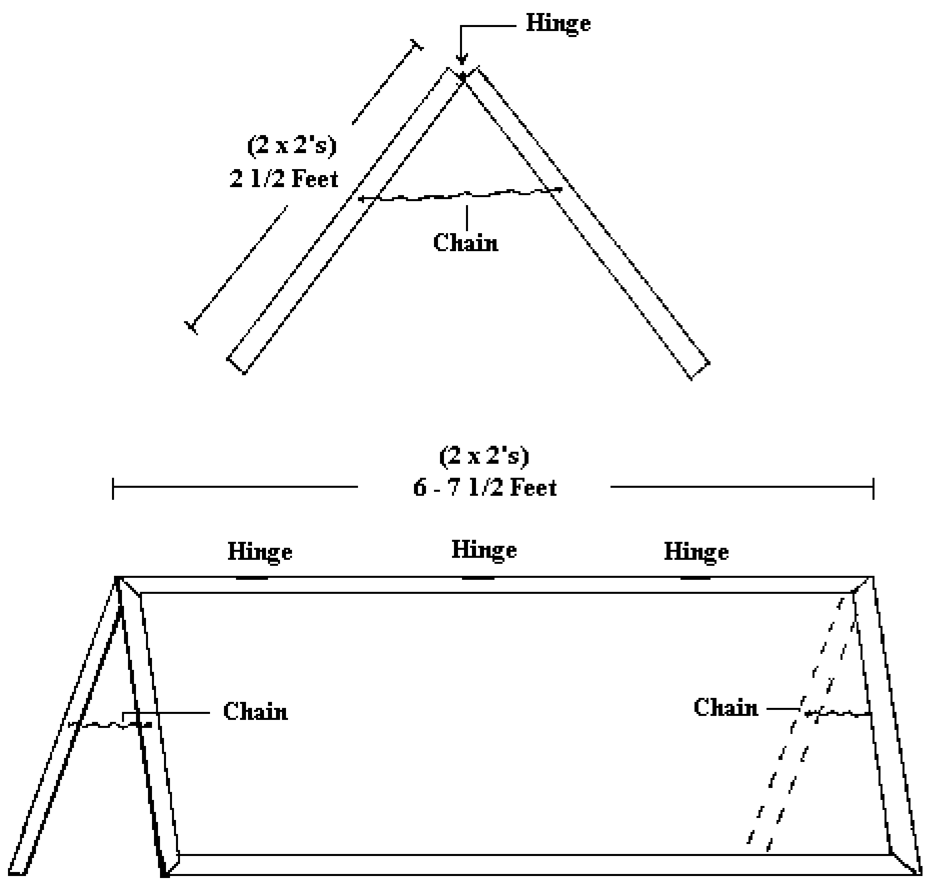
Staple canvas to frame. Make sure if canvas is attached while blind is completely open that enough slack material is left to enable folding blind back together.

The canvas at end of the blind can be left loose or tightened by cutting out extra material and stapling to one side.

Cut camera hole in one end only large enough for camera lens to fit through.

Note: This blind is an inexpensive method of gaining concealment for taking wildlife photographs. Since you must lay flat, it is not the best choice for marshy areas where water covering the ground may be a factor. A dense foam sleeping mattress may be helpful to keep you off the ground. A sandbag or beanbag works well to steady your camera or lens. A tall person may need to start with 7' or 7 1/2' 2x2 lengths.

Low - Profile A-Frame Blind



Modified Portable Fishhouse-Type Blind

This blind is fashioned after the typical portable ice house. Finding someone who owns one may give you a head start before construction.

Materials Needed:

- 2 - 4' 1 1/4" (l " x 2")
- 2 - 4' (2" x 4")
- 2 - 5' (2" x 4")
- 2 - (4' x 4') 3/8" plywood
- 7' x 14' dark canvas
- Drill and 1/16" bit, 3/8" bit
- 8' piano hinge
- Jig saw
- 1 box small wood screws (1/2")
- 1 box medium wood screws (3/4")
- Staple gun with 1/2" staples
- Carpet knife
- 8 - 3" wood screws
- Wood glue
- 8 - 4' lengths of 2" x 1/4" lathe

Cut two 4' 2x4s and two 5' 2x4s. Miter ends 90 degrees.

Make base of blind with above 2x4s by joining mitered ends together. Glue and join together with 3" wood screws.

Use piano hinge on inside edge of blind. Attach to each 4' 2x4 one 4x4 sheet of 3/8" plywood. Use 1/2" screws in plywood and 3/4" screws in 2x4. Both plywood pieces should be free to fold toward center of blind.

Begin attaching canvas on one 5' 2x4. Drill pilot holes in lathe material with 1/16" bit. Double canvas over and place lathe material over canvas. Sink 3/4" screws through lathe, canvas, and into 2x4. Have assistant hold both plywood sides straight up.

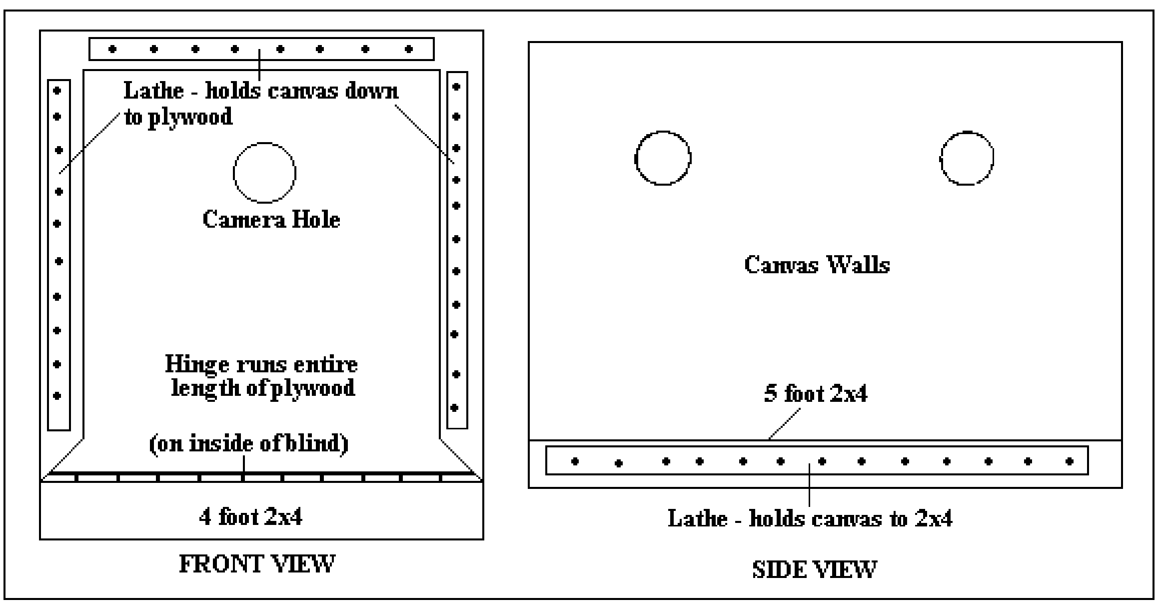
Stretch canvas over entire blind and repeat above process on opposite 5' 2x4. Cutting of some excess canvas may be necessary.

Secure 1x2s inside blind wedging them between plywood walls. These will be the supports that keep your blind from collapsing. For right now, you may wish to nail them temporarily for ease of working.

Attach canvas on plywood by using lathe and 1/2" screws. Remember doubling canvas and drilling pilot holes. Extra canvas will need to be trimmed. Use your own best judgment, however, canvas should overlap wood by at least 3".

Sit in blind with desired stool to determine level you will be photographing. At this level, trace a hole (with coffee can, etc.) slightly larger than your camera lens. Drill hole with 3/8" bit for a spot to start cutting. You may wish to have camera holes in the canvas also. Make flaps to cover holes by using excess canvas. Use velcro to attach flaps to cover unused windows.

Note: This blind is ideal for situations where water is present since the bottom is entirely open. Wear your rubber boots or use a false floor made of a pallet, etc.



<u>Great Trinity Forest Management Plan</u>

Wildlife Management

Woodpecker Excavation and Use of Cavities in Polystyrene Snags

Wilson Bull., 108(3), 1996, pp. 449-456

WOODPECKER EXCAVATION AND USE OF CAVITIES IN POLYSTYRENE SNAGS

RICHARD N. CONNER AND DANIEL SAENZ

ABSTRACT.-We examined woodpecker excavation and use of artificial polystyrene snags in four forest types in eastern Texas for five years. Twenty-three of 47 artificial snags were used by Downy Woodpeckers *(Picoides pubescens)* for cavity excavation and subsequent nocturnal roosting; they did not use the artificial snags for nesting. Although six other species of woodpeckers were present in the area, only Downy Woodpeckers excavated cavities in the artificial cavity substrate. Entrances to cavities in artificial snags became enlarged within several months of excavation. Other wildlife species using abandoned cavities in artificial snags were Carolina Chickadees (*Parus carolinensis*), Prothonotary Warblers (*Protonotaria citrea*), southern flying squirrels (*Glaucomys volans*), and red wasps (*Polistes* sp.). In one instance, Carolina Chickadees excavated their own cavity and nested within a polystyrene snag. Until an artificial cavity substrate acceptable for both woodpecker excavation and nesting can be found, the utility of artificial snags as a means to augment woodpecker nesting substrate remains inadequate. *Received 18 October 199.5, accepted 16 January 1996.*

Many woodpecker species and secondary cavity nesters depend on snags (standing dead trees) for cavity sites that they use for nesting and roosting (Conner 1978, Evans and Conner 1979, Thomas et al. 1979, Raphael and White 1984). Harvesting of mature forests can greatly reduce the availability of substrate for woodpeckers to excavate nest cavities (Conner 1978, Dickson et al. 1983). Thus, artificial cavity substrate may benefit nesting woodpeckers in areas where snag availability is low.

Peterson and Grubb (1983) evaluated woodpecker use of 50 artificial polystyrene snags (242-cm high X 22-cm diameter) over an 1 l-month period in Ohio. Downy Woodpeckers (*Picoides pubescens*) excavated 5 1 cavities in 42 of the snags, used them for nocturnal roosting, but failed to use the cavities for nesting. House Wrens *(Troglodytes aedon)* and Carolina Chickadees (*Parus carolinensis*) nested in cavities excavated by Downy Woodpeckers. Peterson and Grubb (1983) speculated that other larger species of woodpeckers might use polystyrene snags if snags >22-cm diameter were provided, but this idea has never been tested. Artificial polystyrene snags have also been used to explore sexual differences in selection of cavity sites by Downy Woodpeckers and to evaluate cavity entrance orientation and snag selection relative to vegetation in a regenerating clear cut (Grubb 1982, Petit et al. 1985).

We evaluated woodpecker use of 26-cm diameter X 242-cm high poly-

[1] Wildlife Habitat and Silviculture Laboratory (Maintained in cooperation with the College of Forestry, Stephen F. Austin State Univ.), Southern Research Station, USDA Forest Service, Nacogdoches, Texas 75962.

TABLE 1

VEGETATIONAL CHARACTERISTICS (MEANS ± SD) OF MATURE PURE PINE, PINE-HARDWOOD, UPLAND HARDWOOD, AND BOTTOMLAND HARDWOOD FOREST STANDS WHERE ARTIFICIAL POLYSTYRENE SNAGS WERE STUDIED ON THE STEPHEN F. AUSTIN EXPERIMENTAL FOREST IN EASTERN TEXAS

Vegetation variable	Pure pine (N = 20)	Pine-hardwood (N = 20)	Upland hardwood (N = 20)	Bottomland hardwood (N = 20)
Vegetation height (m)	30.0 (3.7)	27.4 (5.5)	20.6 (2.9)	27.1 (5.3)
Pine basal area (m^2/ha)	23.5 (3.9)	22.6 (7.3)	3.8 (3.6)	0.2 (0.5)
Hardwood basal area (m^2/ha)	0.2 (0.6)	4.0 (3.2)	15.6 (3.5)	18.5 (4.8)
Tree density (#/0.04 ha)	11.5 (3.6)	18.5 (9.6)	10.1 (3.2)	14.0 (3.6)
Canopy closure (%)	73.1 (11.1)	71.2 (14.3)	69.3 (13.8)	72.5 (13.0)
Ground cover (%)	2.9 (2.8)	3.5 (2.4)	3.5 (2.7)	9.6 (6.4)
Natural snags (#/0.04 ha)	0.8 (0.8)	0.7 (0.9)	0.7 (0.8)	1.1 (1.0)

styrene snags in four forest types over a five-year period. We determined secondary cavity nester use of woodpecker cavities and evaluated cavity shape and condition with long-term use.

STUDY AREAS AND METHODS

We constructed 47 artificial snags from solid blocks of polystyrene (26-cm diameter X 242-cm high). The 4-cm increase in diameter of the polystyrene snags above what had been used previously (Peterson and Grubb 1983), placed the substrate diameter within the range of sizes used by Hairy (*Picoides villosus*) and Red-bellied (*Melanerpes carolinus*) woodpeckers for cavity sites (Conner 1978). Similar to Peterson and Grubb (1983), we painted the artificial snags with a thick coating of brown latex paint to enhance the snag-like appearance of the polystyrene snags. After drilling a centrally located 3-cm diameter hole (parallel to the length of the snag), 80 cm deep into the base of each artificial snag, we installed it in the field on 20 October 1986 by sliding it onto a 184-cm long "T-pole" (iron fence post) that had been driven into the ground approximately 110 cm deep. The hole drilled into the base of each artificial snag was made solely to mount (impale) the snags on T-poles. All artificial snags were installed as close to vertical as possible, i.e., no lean could be visually detected. Artificial snags were installed at 112-m intervals on four nest box trails in four forest types (ten snags per trail and one trail in each forest type: mature pure pine [*Pinus* spp.], pine-hardwood, upland hardwood, and bottomland hardwood forest habitats) located on the Stephen F. Austin Experimental Forest (31°29'N, 94°47'W) in southern Nacogdoches County, Texas. Each nest box trail was circular and approximately 1130 m in length. Cavities for secondary cavity nesters were readily available on each trail, because 20 sites with three nest boxes per site were established at 56-m intervals on each trail as a part of a different study. Seven additional artificial snags were installed on the edge of mature pine-hardwood forest next to dirt roads.

Vegetation characteristics were measured at 56-m intervals (20 points) on each of the four nest box trails (Table 1). We measured vegetation height with a clinometer, and tree basal areas were measured with a one-factor metric prism. Densities of trees and snags > 15 cm diameter at breast height were counted within an 11.3-m radius circular plot. We esti-

TABLE 2

SPECIES USE OF CAVITIES EXCAVATED BY DOWNY WOODPECKERS IN ARTIFICIAL POLYSTYRENE SNAGS IN FOUR FOREST TYPES ON THE STEPHEN F. AUSTIN EXPERIMENTAL FOREST IN EASTERN TEXAS

	Number of polystyrene snags used			
Cavity occupant	Pure pine (N = 10)	Pine-hardwood[a] (N = 17)	Upland hardwood (N = 10)	Bottomland hardwood (N = 10)
Downy Woodpecker[b]	0	13	10	0
Carolina Chickadee	0	4[c]	2	0
Prothonotary Warbler	0	0	2	0
Southern flying squirrel	0	1	0	0
Red wasps	0	3	2	0

[a] Artificial snags in forest (N = 10) and edge (N = 7) pine-hardwood habitat combined.
[b] All cavities except one were initially excavated by Downy Woodpeckers.
[c] In one instance in pine-hardwood edge habitat Carolina Chickadees excavated their own cavity.

mated percent canopy closure and ground cover, using a 4-cm diameter X 12-cm long hollow tube. We recorded height and compass aspect of pecking and cavity excavation on all artificial snags from fall 1986 to summer 1991.

Occupants of cavities were determined by checking roosts with a mirror, watching occupants use a cavity, or flushing the occupant. Artificial snags were visited during the spring (March-May), fall (September-October), and winter (December-January) during each year of the study. The species of woodpeckers excavating cavities in artificial snags were determined by watching the actual excavation or by measuring the final size of the completed cavity. We also noted claw marks and their relative size to determine if they had been made by a squirrel or a possible predator (house cat [*Felis domesticus*] and raccoon [*Procyon lotor*]). We were not able to determine nesting success on all of the avian nests detected because of time and personnel constraints. Artificial snags in the bottomland hardwood area were monitored only until spring 1989 because flooding lifted the snags off the T-poles and washed them down the Angelina River.

RESULTS

Except for one case, Downy Woodpeckers were the only species detected excavating and using cavities in the artificial polystyrene snags (Table 2). We did not observe Downy Woodpeckers nesting in any of the cavities, but they regularly used the cavities as nocturnal roosts. Downy Woodpeckers excavated cavities in artificial snags only in the pine-hardwood and upland hardwood forest types. Carolina Chickadees were the most frequent secondary users of cavities excavated by Downy Woodpeckers (Table 2). In one instance, Carolina Chickadees excavated a cavity during the early spring and successfully nested in it. Prothonotary Warblers (*Protonotaria citrea*) successfully nested in two different cavities in the upland hardwood forest type. Standing water was present in parts of this area for much of the spring. Five cavities were used by red

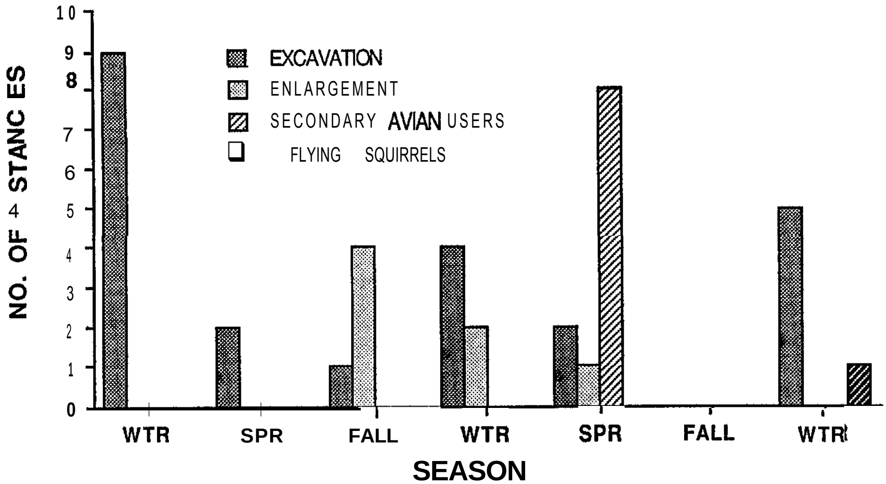


FIG. 1. **Seasonal appearance of cavities completed by Downy Woodpeckers in polystyrene snags (starting in winter 15 months after snag installation), enlargement of cavities by subsequent use, and use by secondary cavity users during successive winter (WTR), spring (SPR), and fall (FALL) seasons on the Stephen F. Austin Experimental Forest in eastern Texas.**

wasps (*Polistes* sp.) and one by southern flying squirrels (*Glaucomys volans*).

Artificial snags were in place five months before small holes began to appear in them in the upland hardwood and pine-hardwood areas during the early spring 1987. Downy Woodpeckers were the only woodpecker species observed excavating cavities in the artificial snags, and the first completed cavities (9) appeared in these two habitat types by early January 1988 (15 months after installation) indicating that they had been excavated during late fall to early winter 1987. Additional completions of cavities in other artificial snags occurred during the next two years (Fig. 1). Avian secondary cavity nesters did not begin to use the completed cavities until more than a year had passed (Fig. 1). Southern flying squirrels were first detected after two years.

All completed cavity entrances were excavated between 12 and 16 cm from the top of the artificial snags. It was difficult to detect visually a preference for cavity orientation. Cavity entrances appeared to be bimodal in their distribution (Fig. 2). A Rao's test indicated a non-random orientation of entrances (U = 1,591; $P < 0.01$).

Small holes that seemed to be similar to cavity starts appeared near the tops of two artificial snags in the pure pine area within five months of snag installation. Cavities in those two snags, however, were never com-

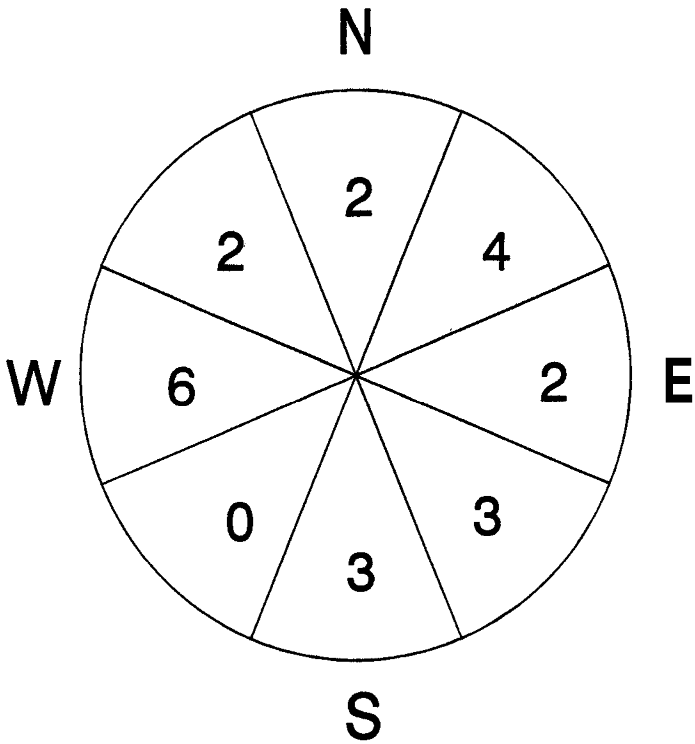


FIG. 2. **Aspects of entrances to cavities excavated into artificial polystyrene snags (N = 22) in eastern Texas.**

pleted. By January 1988, two other artificial snags in the pure pine area had small excavations in them but were also abandoned. Artificial snags in the bottomland hardwood area had small and some large holes excavated within 30 cm of the base of the snags, most likely excavated by Pileated Woodpeckers (*Dryocopus pileatus*). But, apparent start holes in both the pure pine and bottomland hardwood areas were never excavated beyond several centimeters deep. Artificial snags in all areas had varying amounts of their surface paint and polystyrene pecked away, as if woodpeckers or other bark foragers had attempted to forage on them.

Seven cavity entrances became quite enlarged within 8-10 months following cavity completion and subsequent use (Fig. 1). Although entrances enlarged in all directions, the bottom of each entrance was affected the most. Polystyrene would erode away 10–15 cm, most likely during the passage of the occupant, so that entrances gradually became elongated vertically. Downy Woodpeckers appeared to abandon enlarged cavities.

Claw marks of sufficient size to suggest attempted predation appeared on four of the artificial snags with cavities during the fall and winter. In one instance, the cavity entrance was torn open and about half of the cavity chamber exposed.

DISCUSSION

Our attempt to use large diameter polystyrene snags to encourage some of the larger woodpeckers to excavate cavities was unsuccessful. Although both Red-bellied and Hairy woodpeckers were present within the vicinity, neither species apparently excavated cavities in the artificial snags. Diameters of the artificial snags were sufficient to house cavities made by these two species (Conner et al. 1975, Jackson 1976). However, the 3-m height of the artificial snags, which was the tallest block of polystyrene commercially available, may have been too low for these two species. Hairy and Red-bellied woodpeckers typically excavate nest cavities at heights above 3 m (Conner 1978). Downy Woodpeckers often nest in dead tree stubs that are approximately 3 m in height (Conner et al. 1975). They also are known to excavate cavities in very soft, well-decayed natural snags (Conner et al. 1975, 1976). The consistency of polystyrene is very similar to that of well-decayed wood tissue found in some snags used by Downy Woodpeckers for cavity excavation. Both the polystyrene and well-decayed wood tissue can be easily excavated by a human finger nail. Substrate of such little structural strength may be too soft for the larger woodpecker species.

Although there were woodpeckers within the pure pine and bottomland hardwood study areas, none of the polystyrene snags in these study areas was used for cavity excavation. There was an abundance of natural snags in the bottomland habitat (Conner et al. 1994, Table 1); thus, the attractiveness of artificial snags was likely less. Natural snags were as common in the pure pine stand as they were in the pine-hardwood study area (Table 1). The failure of Downy Woodpeckers to use artificial snags in the pure pine stand is enigmatic.

The long term value of polystyrene snags as an artificial substrate for woodpecker cavity excavation appears to be relatively low. Only Downy Woodpeckers excavated cavities, and they did not nest in the cavities following excavation. The artificial snags do appear to have some value as roosting sites for Downy Woodpeckers, and the polystyrene material is well known for its high insulating ability, which would be particularly valuable during winter at northern latitudes. Although woodpeckers did not use the cavities for nesting, secondary cavity nesters such as Prothonotary Warblers and Carolina Chickadees successfully nested in the artificial substrate. Entrances to cavities, however, soon begin to erode away with use, rendering the cavity unusable after several years. This problem could be rectified by reinforcing cavity entrances with wire mesh or thin wood following the woodpecker's completion of the cavity chamber.

Still, artificial substrates for woodpecker cavity excavation may have value. Substrates with a stronger yet brittle structure may be needed to entice other woodpecker species to excavate cavities and Downy Woodpeckers to nest. Also, additional structure strength or hardness is needed on the surface of the artificial snags. Such strength might help deter predators and provide sufficient hardness and resonance for mutual tapping behavior and drumming which occur during cavity site selection (Kilham 1958, 1983). Also, further study using larger diameter and taller artificial snags in areas where natural snags are limited or absent may provide additional insight.

ACKNOWLEDGMENTS

We thank T. C. Grubb, Jr., D. R. Petit, and J. R. Walters for constructive comments on an early draft of the manuscript.

LITERATURE CITED

CONNER, R. N. 1978. Snag management for cavity nesting birds. Pp. 120-138 in Proc. of the workshop; management of southern forests for nongame birds (R. M. DeGraaf, tech. coord.). U.S. For. Serv. Gen. Tech. Rep. SE-14.

———, R. G. HOOPER, H. S. CRAWFORD, AND H. S. MOSBY. 1975. Woodpecker nesting habitat in cut and uncut woodlands in Virginia. J. Wildl. Manage. 39:144–150.

———, 0. K. MILLER, JR., AND C. S. ADKISSON. 1976. Woodpecker dependence on trees infected by fungal heart rots. Wilson Bull. 88:575–581.

———, S. D. JONES, AND G. D. JONES. 1994. Snag condition and woodpecker foraging ecology in a bottomland hardwood forest. Wilson Bull. 106:242–257.

DICKSON, J. G., R. N. CONNER, AND J. H. WILLIAMSON. 1983. Snag retention increases bird use of a clear-cut. J. Wildl. Manage. 47:799–804.

EVANS, K. E. AND R. N. CONNER. 1979. Snag management. Pp. 214-224 in Management of north central and northeastern forests for nongame birds (R. M. DeGraaf, tech. coord.). U.S. For. Serv. Gen. Tech. Rep. NC-51.

GRUBB, T. C., JR. 1982. Downy Woodpecker sexes select different cavity sites: an experiment using artificial snags. Wilson Bull. 94:577–579.

JACKSON, J. A. 1976. A comparison of some aspects of the breeding ecology of Red-headed and Red-bellied woodpeckers in Kansas. Condor 78:67–76.

KILHAM, L. 1958. Pair formation, mutual tapping and nest hole selection of Red-bellied Woodpeckers. Auk 75:318–329.

———. 1983. Life history studies of woodpeckers of eastern North America. Nuttall Ornithol. Club # 20.

PETERSON, A. W. AND T. C. GRUBB, JR. 1983. Artificial trees as a cavity substrate for woodpeckers. J. Wildl. Manage. 47:790–798.

PETIT, D. R., K. E. PETIT, T. C. GRUBB, JR., AND L. J. REICHHARDT. 1985. Habitat and snag selection by woodpeckers in a clear-cut: an analysis using artificial snags. Wilson Bull. 97:525–533.

RAPHAEL, M. G. AND M. WHITE. 1984. Use of snags by cavity-nesting birds in the Sierra Nevada. Wildl. Monogr. No. 86.

THOMAS, J. W., R. G. ANDERSON, C. MASER, AND E. L. BULL. 1979. Snags. Pp. 60-77 *in* Wildlife habitats in managed forests, the Blue Mountains of Oregon and Washington (J. W. Thomas, tech. ed.). U.S. For. Serv. Agric. Handbk. No. 553.

<u>Great Trinity Forest Management Plan</u>

Wildlife Management

Brush Sculpting for Nongame Birds

TEXAS PARKS & WILDLIFE

BRUSH SCULPTING FOR NONGAME BIRDS

Matt Wagner, Technical Guidance Biologist, College Station

Introduction

Nongame wildlife consists of those species not classified as game animals or endangered species. There are over 940 species of terrestrial vertebrates in Texas, of which 87% are considered nongame wildlife. Nearly two-thirds (about 600 species) are resident or migratory birds, more than any other state.

Since over 97% of the more than 175 million acres of habitat in Texas is privately owned, this diversity of wildlife provides a conservation challenge to resource managers attempting to maintain habitat while deriving a sustainable economic return from the land.

In 1991, hunters totaled about 1.1 million in Texas, or about 8% of the population. They contributed over a billion dollars that year in pursuit of their activity (U.S. Fish and Wildlife Service, 1991). This economic fact translates into a financial incentive for landowners to maintain and enhance habitat for game species. At the same time, bird watching and other “nonconsumptive” wildlife recreation was on the increase as our urban population continued to grow. According to the 1994-95 National Survey on Recreation and the Environment (NSRE), the number of bird watchers, or “birders”, grew about 155% between 1983 and 1995. This trend can be expected to continue in the years ahead as wildlife watching, in general, becomes more important.

Surveys indicate that birding and other wildlife watching has the potential to provide an alternate source of revenue for private landowners. In fact, several private ranches in Texas are already offering nature tours on a fee basis.

Management practices that will enhance a diversity of wildlife species are an important consideration for landowners. Even more important is the opportunity to educate this growing group of outdoor users as to why private land management is necessary to sustain wildlife populations in Texas.

Nongame birds include:

1) Neotropical migrants, those species that breed in North America and winter in the New World tropics
2) Short distance migrants, which breed in more northerly latitudes and winter primarily in the southern U.S. and northern Mexico
3) Permanent residents, which remain year-round in a particular region or site.

Raptors, woodpeckers, shorebirds, and other waterbirds fall within these categories, but passerine birds (perching and songbirds) are by far the largest group.

Opportunities for conservation of these species occur on both the breeding and wintering grounds. Texas Partners in Flight is an organization dedicated to the improvement of monitoring, research, management, and education programs for neotropical migratory birds and their habitats. According to the Partners in Flight strategy, the priority species in need of attention in Texas are ranked according to their regional distribution in the Southeastern U.S.

The birds discussed in this paper represent selected habitats in the Rolling Plains, Cross-Timbers, Edwards Plateau, and South Texas ecological regions of Texas, but they occur in other ecological regions of the state as well. Managing habitat for these species will benefit an assemblage of many other important nongame bird species.

Grasslands

In North America, researchers and bird enthusiasts have identified grassland birds as having experienced steeper, more consistent, and more widespread population declines over the last quarter century than any other avian guild (Vickery et al 1995). The reasons for these declines have not been fully determined, but habitat loss appears to be one of the major factors on both the breeding and wintering grounds.

Grassland birds nest on or near the ground, and are associated with tall, intermediate, or short grass heights depending on the species requirements for nesting and cover. Native prairies are a rare thing in Texas today as most have been converted by cultivation, or are in poor condition due to woody plant invasion. Remnant prairies can still be found scattered throughout Texas.

In the Rolling Plains, the upland sandpiper breeds in mixed grasslands, while key passerine species inhabiting tall grass prairie habitats in the Cross Timbers Region are LeConte’s sparrow (winter) and grasshopper sparrow (breeding). While overlap occurs between ecological regions in these bird's distribution, they all require open grasslands, and serve as indicators of good habitat conditions for other prairie-dependent species.

Brush management practices that restore or maintain native prairies will benefit grassland birds and many other nongame species. Woody plants growing in and around small prairies provide habitat and perch sites for potential predators including raptors. Prescribed fire will control encroaching brush species, but mature plants need to be treated individually using selective herbicides or mechanical means. Treatments should be conducted in the late summer or early fall after the breeding season and before wintering species arrive. Invading woody plant species in the Rolling Plains and Cross-Timbers include mesquite, red-berry juniper, eastern red cedar, baccharis, various oaks, yaupon, elms, Russian olive, and others. Prairie restoration should be conducted on priority sites based on soil type, acreage, distribution of potential and existing habitat, and current condition of habitat.

Some bird species are "area-sensitive" and require relatively large, undisturbed tracts of suitable habitat for their survival. Grasslands as large as 250 acres may have a 50% likelihood of attracting grassland species that are highly sensitive to habitat fragmentation (Herkert et al 1993). Thus, restoring prairie habitats that link together small parcels will lessen the effects of fragmentation.

Private lands enrolled in the Conservation Reserve Program (CRP) may provide additional nesting habitat for many grassland nesting birds species by providing residual cover of appropriate height and density. Averages of 1.5 grasshopper sparrow nests per acre were found in CRP fields in the southern High Plains of Texas (Berthelsen and Smith 1995). CRP lands should be seeded with native grasses and forbs and kept brush-free during the establishment phase. Periodic prescribed burning may maintain and enhance the quality of these tracts over the life of the contract. Restoration of native prairies should be planned adjacent or in close proximity to CRP lands in order to expand the total acreage of habitat suitable for prairie species.

Savannah/Shrubland Habitats

Savannah's are typically grasslands with scattered woody vegetation. Mesquite and live oak savannahs are found predominantly in the Rolling Plains and Edwards Plateau regions respectively, while post oak and blackjack oak may become dominant species in the Cross-Timbers Region. However, past mismanagement has changed the savannah condition, resulting in a "thicketized" understory with invading plants such as junipers, sumacs, elms and hackberries. Although these plants have wildlife value as food and shelter for many game and nongame species, they become detrimental when over-abundant, and begin to out-compete native grasses and forbs that are essential components in savannah habitats.

Shrublands can be considered successional landscapes, supporting brush species of lower stature usually after some form of mechanical brush control, prescribed burning, or intensive grazing. Periodic management is required to keep these habitats from maturing beyond the point of usefulness to the species that require them. Savannahs and shrublands are similiar in that both are transitional habitats between open grasslands and wooded habitats. Active management is required to mimic the natural disturbances historically caused by wind and fire, and create the habitats in large enough areas for the species adapted to them (DeGraaf and Rappole 1995).

Examples of species breeding in these habitats in the Rolling Plains, Cross-Timbers, Edwards Plateau, and South Texas regions are: lark bunting, loggerhead shrike, yellow-breasted chat, painted bunting, ash-throated flycatcher, and blue grosbeak. In the northern portions of its Texas range, the field sparrow is a resident of these habitats, while South Texas is home to this bird in winter.

Savannah or successional habitats should be integrated into an overall management scheme for a particular site based upon what the potential vegetation is, and what other habitats are present. For example, old fields, borrow areas, or other disturbed sites may be logical choices because many times they are already undergoing some form of succession. Brush management practices to restore, maintain, or enhance a savannah or shrubland setting should include native woody plant establishment, thinning undesirable or exotic plants by using selective herbicides on individual plants, mechanical treatments, and prescribed burns to control young brush species without killing mature trees. If brush is cut and removed, the appropriate herbicide should be applied to the stump surface to prevent re-sprouting. Cut debris should be stacked into piles to provide cover for other nongame species. If prescribed fire is used, burning in to woodland edges instead of away from them will promote a more “feathered” edge, thus creating a buffer or transition area instead of abrupt edges.

Clumps of scattered brush interspersed with herbaceous vegetation will create “mini-mottes” containing a diversity of plant species and structural layers. This, in turn, benefits a wider variety of nongame species. As shrubs mature, it will be necessary to top-kill them before reaching a height beyond the usefulness of the target species for nesting or cover. Fire is generally the best way to achieve this, but mechanical treatment may be more applicable where burning is not possible or does not create the desired results. Again, late summer or early fall is the best time to initiate management practices so as to avoid nesting season, thus allowing young birds to fledge normally. Prescribed burning is generally conducted in the winter months, but late summer burns are being investigated as a means of re-creating mesquite savannah (Ansley 1997).

Woodland and Riparian Areas

Woodlands are forested habitats occurring in large blocks, small patches, or irregular corridors. They typically support a diversity of overstory trees and understory shrubs that provide food in the form of fruits, nuts and berries as well as vertical layers important for nesting and cover for a wide variety of nongame birds. The amount of plant canopy cover, height, and species diversity are important factors in determining which bird species will use wooded habitats. In general, a higher plant diversity will support a greater diversity of wildlife.

Some woodlands occur along the margins of streams, rivers, lakes or other water features. These specialized habitats are known as riparian areas and represent some of the most biologically rich and unique habitats in Texas. Riparian areas also act as filters for excess nutrient runoff, and prevent erosion when vegetation is properly managed. Although less than 4 % of the state’s land area is made up of riparian-type vegetation, higher numbers of wildlife and a greater diversity of species are found in these areas than in other habitats. Dominant trees of riparian areas include cottonwood, black willow, and mesquite in the Rolling Plains, and pecan, sycamore, ash and bald cypress in the Cross-Timbers and Edwards Plateau regions.

The red-headed woodpecker is a resident species typical of woodland and riparian areas of the Rolling Plains, while the Baltimore oriole breeds in similar habitat in the Cross-Timbers. The black-and-white warbler is representative of oak-juniper woodlands, and yellow-throated warblers and green kingfishers inhabit riparian areas of the Edwards Plateau. Curve-billed thrashers can be found nesting in upland thorn woodlands typical of much of South Texas, while Bell’s vireos uses the more mesic riparian habitats in the same region.

In woodlands, habitat patch size can be a limiting factor for successful reproduction of many interior-nesting bird species. When large openings are created in woodland habitats, nest predators and the brown-headed cowbird, a nest parasite, are more likely to gain access to interior-nesting species. Depending on the goals of the land manager and the amount of contiguous woodlands in close proximity to the property, it may be desirable to re-forest existing openings with native trees to create a continuous closed canopy.

On the other hand, highly fragmented wooded patches surrounded by openings in various successional stages may not become suitable tracts for interior species no matter what the management strategy is. Leaving or restoring connective corridors between cleared patches may reduce the effects of fragmentation. Where needed, plant a diversity of native food-producing trees. Consider using simple techniques such as setting fence posts connected with a single smooth wire 48 inches above the ground. This will provide perching sites for birds to deposit seeds in the appropriate area.

In addition, buffer zones of wooded habitat along riparian areas should be at least 150 feet on each side of the stream. This not only provides cover for wildlife movement between tracts of habitat, but also serves to stabilize stream banks and filter runoff. Protect young, establishing trees and shrubs from over-browsing by livestock using temporary electric fencing, or construct permanent fencing to control the intensity, timing, and location of grazing in woodlands and riparian areas.

Over-browsing by deer can be managed by reducing their abundance through high fencing, hunting, or trapping and relocation, none of which offer a practical, long-term solution in most situations.

Mechanical brush control treatments have been applied to millions of acres of Texas rangelands. After soil disturbance, a less diverse woody plant community normally regenerates (Fulbright 1996). As plant diversity decreases, wildlife diversity will decrease as well, depending on the scale of the land use. Bird diversity may decrease on a particular site, but diversity across a landscape may actually increase depending on surrounding land-use practices, habitats, and corresponding bird species.

In woodland, riparian or other sensitive habitats, the selective control of exotic plants or other undesirable species can be conducted by hand-cutting, girdling or selective herbicide applications. Apply the appropriate herbicide directly to the cut stump surface to prevent re-sprouting. Basal bark treatments or the "hack and squirt" method can be used to kill undesirable trees without impacting surrounding plants. This also creates snags for cavity-nesting species.

Snags are extremely important for a wide variety of nongame wildlife including woodpeckers, screech owls, chickadees, titmice, squirrels, bats, and other small mammals. Six snags and/or den trees per acre of woodland is considered adequate for most kinds of wildlife (Missouri Department of Conservation 1985).

A Word About Small Acreage Management

One of the greatest threats to wildlife habitat in Texas today is the subdivision of large land holdings into smaller tracts. Changes in estate tax structure, improvements in maintaining production agriculture on suitable land, and controlled, sustainable commercialization (i.e., hunting and nature tourism) of key resident wildlife will slow this trend (DeGraaf and Rappole 1995). But ultimately, as human populations continue to grow, resource managers will be forced to develop technologies to restore and maintain habitat fragments in order to support viable wildlife populations.

Under these conditions, corridors or "linear habitats" become increasingly important. Fence lines, drainages, roadways, or other mutual boundaries are all potential linear habitats that, when linked together, may create key travel corridors for wildlife moving to and from larger tracts of habitat.

Cooperative efforts involving multiple landowners within managed units such as local parks, homeowners associations or watersheds must become commonplace if strategies for the future of wildlife in Texas are going to be successful.

With the passage of Proposition 11 in 1995, landowners can now retain their agricultural property tax valuation if their land use changes to active wildlife management. This will ultimately have a positive effect on wildlife as small land holdings, forced to carry livestock for tax purposes, receive much needed deferment. The techniques for managing many nongame species are now available through the Texas Wildscape Program, administered by the Texas Parks and Wildlife Department.

Literature Cited

Ansley, R.J., B.A. Kramp, and T.L. Moore. 1997. Development and management of mesquite savanna using low intensity prescribed fires. Proceedings, First Conference on Fire Effects on Threatened and Endangered Species and Habitats, International Association of Wildland Fire, Coeur d'Alene, ID, 13-15 November 1995 (In press).

Berthelsen. P.S. and L.M. Smith. 1995. Nongame bird nesting on CRP lands in the Texas Southern High Plains. J. Soil and Water Conservation. 50(6) pp. 672-675.

Damude, Noreen. 1997. Pers. Comm.

DeGraaf, R.M., V.E. Scott, R.M. Hamre, L. Ernst, and S.H. Anderson. 1991. Forest and Rangeland Birds of the United States - Natural History and Habitat Use. U. S. Dep. Agr. Handbook 688.

DeGraaf, R.M. and J.H. Rappole. 1995. Neotropical Migratory Birds - Natural History, Distribution, and Population Change. Comstock Publ. Assoc., Cornell Univ. Press.

Fulbright, T.E. 1996. Viewpoint: A theoretical basis for planning woody plant control to maintain species diversity. J. Range Manage. 49(6) pp. 554-559.

Herkert, J.R., R.E. Szafoni, V.M. Kleen, and J.E. Schwegman.1993. Habitat establishment, enhancement and management for forest and grassland birds in Illinois. Div. Natural Heritage, Illinois Dep. Conserv., Natural Heritage Pub. #1.

Missouri Department of Conservation. 1985. Snag and den tree management. Timber and Wildlife Benefits on Private Land. No. 5.

National Geographic Society. 1980. *Field Guide to the Birds of North America*. Washington, DC National Geographic Society.

Riley, C.M., ed. 1996*. Texas Partners in Flight Priority List for Texas Bird Conservation*. Tex. Parks and Wild. Dept. PWD BK W7100-292. 111pp.

U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census. *1991 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation*. U.S. Government Printing Office, Washington DC 1993.

Vickery, P.D., J.R. Heckert, F.L. Knopf, J. Ruth, and C.E. Keller. 1995. An overview of threats and recommended management strategies. Unpublished proceedings of the National Partners in Flight Meeting, Cape May, New Jersey.

Great Trinity Forest Management Plan

Wildlife Management

Reptiles and Amphibians of Dallas County

Salamanders

Ambystomatidae (Mole Salamanders)

- Ambystoma
  - Ambystoma maculatum (Spotted Salamander)
  - Ambystoma opacum (Marbled Salamander)
  - Ambystoma talpoideum (Mole Salamander)
  - Ambystoma texanum (Smallmouth Salamander)
  - Ambystoma tigrinum mavortium (Barred Tiger Salamander)
  - Ambystoma tigrinum tigrinum (Eastern Tiger Salamander)

Amphiumidae (Amphiumas)

- Amphiuma
  - Amphiuma tridactylum (Three-toed Amphiuma)

Proteidae (Mudpuppies, Waterdogs)

- Necturus
  - Necturus beyeri (Gulf Coast Waterdog)

Plethodontidae (Lungless Salamanders)

- Desmognathus (Dusky Salamanders)
  - Desmognathus auriculatus (Southern Dusky Salamander)
- Eurycea (Brook Salamanders)
  - Eurycea latitans (Cascade Caverns Salamander)
  - Eurycea nana (San Marcos Salamander)
  - Eurycea neotenes (Texas Salamander)
  - Eurycea quadridigitata (Dwarf Salamander)
  - Eurycea sosorum (Barton Springs Salamander)
  - Eurycea tridentifera (Comal Blind Salamander)
  - Eurycea troglodytes (Valdina Farms Salamander)
- Plethodon
  - Plethodon glutinosus complex (Slimy Salamander)
    - Plethodon albagula (Western Slimy Salamander)
  - Plethodon serratus (Southern Redback Salamander)
- Typhlomolge
  - Typhlomolge rathbuni (Texas Blind Salamander)
  - Typhlomolge robusta (Blanco Blind Salamander)

Salamandridae (Newts)

- Notophthalmus
  - Notophthalmus meridionalis (Black-spotted Newt)

    - Notophthalmus viridescens (Eastern Newt)

Sirenidae (Sirens)

- Siren
    - Siren intermedia nettingi (Eastern Lesser Siren)
    - Siren intermedia texana (Rio Grande Lesser Siren)

Frogs and Toads

Bufonidae

- Bufo (Toads)
  - Bufo americanus (American Toad)
  - Bufo cognatus (Great Plains Toad)
  - Bufo debilis (Green Toad)
  - Bufo houstonensis (Houston Toad)
  - Bufo marinus (Giant Toad)
  - Bufo punctatus (Red-spotted Toad)
  - Bufo speciosus (Texas Toad)
  - Bufo valliceps (Gulf Coast Toad)
  - Bufo woodhousii (Woodhouse's Toad)

Hylidae (Treefrogs)

- Acris (Cricket Frogs)
  - Acris crepitans (Northern Cricket Frog)
- Hyla (Treefrogs)
  - Hyla arenicolor (Canyon Treefrog)
  - Hyla chrysoscelis (Cope's Gray Treefrog)
  - Hyla cinerea (Green Treefrog)
  - Hyla squirella (Squirrel Treefrog)
  - Hyla versicolor (Gray Treefrog)
- Pseudacris (Chorus Frogs)
  - Pseudacris clarkii (Spotted Chorus Frog)
  - Pseudacris crucifer (Spring Peeper)
  - Pseudacris streckeri (Strecker's Chorus frog)
  - Pseudacris triseriata (Western Chorus Frog)
- Smilisca
  - Smilisca baudinii (Mexican Treefrog)

Leptodactylidae (Tropical Frogs)

- Hylactophryne (Barking Frogs)
  - Hylactophryne augusti (Eastern Barking Frog)
- Leptodactylus
  - Leptodactylus fragilis (White-lipped Frog)
- Syrrhophus (Chirping Frogs)
  - Syrrhophus cystignathoides (Chirping Frog)
  - Syrrhophus guttilatus (Spotted Chirping Frog)
  - Syrrhophus marnockii (Cliff Chirping Frog)

Microhylidae (Narrowmouth Toads)

- Gastrophryne (Narrowmouth Toads)
    - Gastrophryne carolinensis (Eastern Narrowmouth Toad)
    - Gastrophryne olivacea (Great Plains Narrowmouth Toad)
- Hypopachus (Sheep Frogs)
    - Hypopachus variolosus (Sheep Frog)

Pelobatidae (Spadefoot Toads)

- Scaphiopus (Spadefoot Toads)
    - Scaphiopus couchii (Couch's Spadefoot)
    - Scaphiopus hurterii (Hurter's Spadefoot)
- Spea (Spadefoot Toads)
    - Spea bombifrons (Plains Spadefoot)
    - Spea multiplicata (New Mexico Spadefoot)

Ranidae (True Frogs)

- Rana (True Frogs)
    - Rana areolata (Crawfish Frog)
    - Rana berlandieri (Rio Grande Leopard Frog)
    - Rana blairi (Plains Leopard Frog)
    - Rana catesbeiana (Bullfrog)
    - Rana clamitans clamitans (Bronze Frog)
    - Rana grylio (Pig Frog)
    - Rana palustris (Pickerel Frog)
    - Rana sphenocephala (Leopard Frog)

Rhinophrynidae

- Rhinophrynus
    - Rhinophrynus dorsalis (Mexican Burrowing Toad)

Turtles

Cheloniidae (Marine Turtles)

- Caretta
  - Caretta caretta (Loggerhead)
- Chelonia
  - Chelonia mydas (Green Turtle)
- Eretmochelys
  - Eretmochelys imbricata (Hawksbill)
- Lepidochelys
  - Lepidochelys kempii (Atlantic Ridley)

Chelydridae (Snapping Turtles)

- Chelydra
  - Chelydra serpentina (Common Snapping Turtle)
- Macroclemys
  - Macroclemys temminckii (Alligator Snapping Turtle)

Dermochelidae (Leatherback Turtles)

- Dermochelys
  - Dermochelys coriacea (Leatherback)

Emydidae (Water and Box Turtles)

- Chrysemys (Painted Turtles)
  - Chrysemys picta (Painted Turtle)
- Deirochelys (Chicken Turtles)
  - Deirochelys reticularia (Chicken Turtle)
- Graptemys (Map Turtles)
  - Graptemys caglei (Cagle's Map Trtle)
  - Graptemys ouachitensis (Oachita Map Turtle)
  - Graptemys pseudogeographica (False Map Turtle)
  - Graptemys versa (Texas Map Turtle)
- Malaclemys (Diamondback Terrapins)
  - Malaclemys terrapin (Diamondback Terrapin)
- Pseudemys (River Cooters)
  - Pseudemys concinna (Eastern River Cooter)
  - Pseudemys texana (Texas River Cooter)
- Terrapene (Box Turtles)
  - Terrapene carolina (Eastern Box Turtle)
  - Terrapene ornata (Ornate Box Turtle)
- Trachemys (Sliders)
  - Trachemys gaigeae (Big Bend Slider)

- Trachemys scripta (Slider)

Kinosternidae (Mud and Musk Turtles)

- Kinosternon (Mud Turtles)
  - Kinosternon flavescens (Yellow Mud Turtle)
  - Kinosternon hirtipes (Mexican Mud Turtle)
  - Kinosternon subrubrum (Eastern Mud Turtle)
- Sternotherus (Musk Turtles)
  - Sternotherus carinatus (Razorback Musk Turtle)
  - Sternotherus odoratus (Common Musk Turtle)

Testudinidae (Gopher Tortoises)

- Gopherus
  - Gopherus berlandieri (Texas Tortoise)

Trionychidae (Softshell Turtles)

- Apalone
  - Apalone mutica (Smooth Softshell)
  - Apalone spinifera (Spiny Softshell)

Lizards

Anguidae (Anguid Lizards)

- Gerrhonotus
  - Gerrhonotus infernalis (Texas Alligator Lizard)
- Ophisaurus
  - Ophisaurus attenuatus (Slender Glass Lizard)

Crotaphytidae (Collared and Leopard Lizards)

- Crotaphytus (Collared Lizards)
  - Crotaphytus collaris (Eastern Collared Lizard)
  - Crotaphytus reticulatus (Reticulate Collared Lizard)
- Gambelia (Leopard Lizards)
  - Gambelia wislizenii (Longnose Leopard Lizard)

Gekkonidae (Geckos)

- Coleonyx
  - Coleonyx brevis (Texas Banded Gecko)
  - Coleonyx reticulatus (Reticulated Gecko)
- Cyrtodactylus
  - Cyrtodactylus scaber (Bent-toed Gecko)
- Hemidactylus
  - Hemidactylus turcicus turcicus (Mediterranean Gecko)

Iguanidae (Iguanid Lizards)

- Ctenosaura
  - Ctenosaura pectinata (Spinytail Iguana)

Phrynosomatidae (Sand, Horned, and Spiny Lizards)

- Cophosaurus
  - Cophosaurus texanus (GreaterEarless Lizard)
- Holbrookia
  - Holbrookia lacerata (Spot-tailed Earless Lizard)
  - Holbrookia maculata (Lesser Earless Lizard)
  - Holbrookia propinqua (Keeled Earless Lizard)
- Phrynosoma (Horned Lizards)
  - Phrynosoma cornutum (Texas Horned Lizard)
  - Phrynosoma douglassii (Short-horned Lizard)
  - Phrynosoma modestum (Roundtail Horned Lizard)
- Sceloporus
  - Sceloporus graciosus (Sagebrush Lizard)

- Sceloporus grammicus (Mesquite Lizard)
  - Sceloporus magister (Twin-spotted Spiny Lizard)
  - Sceloporus merriami (Canyon Lizard)
  - Sceloporus olivaceus (Texas Spiny Lizard)
  - Sceloporus poinsettii (Crevice Spiny Lizard)
  - Sceloporus serrifer (Blue Spiny Lizard)
  - Sceloporus undulatus (Fence/Prairie Lizard)
  - Sceloporus variabilis (Rosebelly Lizard)
- Urosaurus
  - Urosaurus ornatus (Tree Lizard)
- Uta
  - Uta stansburiana (Desert Side-blotched Lizard)

Polychrotidae (Anoles and Their Relatives)

- Anolis
  - Anolis carolinensis (Green Anole)
  - Anolis sagrei (Brown Anole)

Scincidae (Skinks)

- Eumeces
  - Eumeces anthracinus pluvialis (Southern Coal Skink)
  - Eumeces fasciatus (Five-lined Skink)
  - Eumeces laticeps (Broadhead Skink)
  - Eumeces multivirgatus epipleurotus (Variable Skink)
  - Eumeces obsoletus (Great Plains Skink)
  - Eumeces septentrionalis obtusirostris (Southern Prairie Skink)
  - Eumeces tetragrammus (Four-Lined Skink)
- Scincella
  - Scincella lateralis (Ground Skink)

Teiidae (Whiptails)

- Cnemidophorus
  - Cnemidophorus dixoni (Gray-checkered Whiptail)
  - Cnemidophorus exsanguis (Chihuahuan Spotted Whiptail)
  - Cnemidophorus gularis (Texas Spotted Whiptail)
  - Cnemidophorus inornatus heptagrammus (Trans-Pecos Striped Whiptail)
  - Cnemidophorus laredoensis (Laredo Striped Whiptail)
  - Cnemidophorus marmoratus (Marbled Whiptail)
  - Cnemidophorus neomexicanus (New Mexico Whiptail)
  - Cnemidophorus septemvittatus (Plateau Spotted Whiptail)
  - Cnemidophorus sexlineatus (Six-lined Racerunner)
  - Cnemidophorus tesselatus (Checkered Whiptail)
  - Cnemidophorus uniparens (Desert Grassland Whiptail)

Snakes

Leptotyphlopidae (Blind Snakes)

- Leptotyphlops (Blind Snakes)
  - Leptotyphlops dulcis (Texas Blind Snake)
  - Leptotyphlops humilis (Trans-Pecos Blind Snake)

Colubridae

- Arizona (Glossy Snakes)
  - Arizona elegans (Eastern Glossy Snake)
- Bogertophis
  - Bogertophis subocularis (Trans-Pecos Rat Snake)
- Carphophis (Worm Snakes)
  - Carphophis vermis (Western Worm Snake)
- Cemophora (Scarlet Snakes)
  - Cemophora coccinea (Scarlet Snake)
- Coluber (Racers)
  - Coluber constrictor (Eastern Racer)
- Coniophanes
  - Coniophanes imperialis (Black-striped Snake)
- Diadophis (Ringneck Snakes)
  - Diadophis punctatus (Ringneck Snake)
- Drymarchon (Indigo Snakes)
  - Drymarchon corais (Texas Indigo Snake)
- Drymobius
  - Drymobius margaritiferus (Speckled Racer)
- Elaphe (Rat Snakes)
  - Elaphe bairdi (Baird's Rat Snake)
  - Elaphe emoryi (Great Plains Rat Snake)
  - Elaphe guttata (Corn Snake)
  - Elaphe obsoleta (Eastern Rat Snake)
- Farancia (Mud and Rainbw Snakes)
  - Farancia abacura (Mud Snake)
- Ficimia
  - Ficimia streckeri (Mexican Hooknose Snake)
- Gyalopion
  - Gyalopion canum (Western Hooknose Snake)
- Heterodon (Hognose Snakes)
  - Heterodon nasicus (Western Hognose Snake)
  - Heterodon platirhinos (Eastern Hognose Snake)
- Hypsiglena (Night Snakes)
  - Hypsiglena torquata (Night Snake)
- Lampropeltis (Kingsnakes and Milk Snakes)
  - Lampropeltis alterna (Gray-banded Kingsnake)

- o [Lampropeltis calligaster (Prairie Kingsnake)]
  - o [Lampropeltis getula (Common Kingsnake)]
  - o [Lampropeltis triangulum (Milk Snake)]
- Leptoderia
  - o [Leptoderia septentrionalis (Northern Cat-eyed Snake)]
- Liochlorophis
  - o [Liochlorophis vernalis (Smooth Green Snake)]
- Masticophis (Coachwhip Snakes and Whipsnakes)
  - o [Masticophis flagellum (Coachwhip Snake)]
  - o [Masticophis schotti (Schott's Whipsnake)]
  - o [Masticophis taeniatus (Striped Whipsnake)]
- Nerodia (Water Snakes)
  - o [Nerodia clarkii (Gulf Salt Marsh Snake)]
  - o [Nerodia cyclopion (Mississippi Green Water Snake)]
  - o [Nerodia erythrogaster (Plainbelly Water Snake)]
  - o [Nerodia fasciata (Southern Water Snake)]
  - o [Nerodia harteri (Brazos Water Snake)]
  - o [Nerodia paucimaculata (Concho Water Snake)]
  - o [Nerodia rhombifer (Diamondback Water Snake)]
- Opheodrys (Green Snakes)
  - o [Opheodrys aestivus (Rough Green Snake)]
- Pituophis
  - o [Pituophis catenifer (Gopher Snake)]
  - o [Pituophis ruthveni (Louisiana Pine Snake)]
- Regina (Crayfish Snakes)
  - o [Regina grahamii (Graham's Crayfish Snake)]
  - o [Regina rigida (Gulf Crayfish Snake)]
- Rhinocheilus (Longnose Snakes)
  - o [Rhinocheilus lecontei (Longnose Snake)]
- Salvadora (Patchnose Snakes)
  - o [Salvadora deserticola (Big Bend Patchnose Snake)]
  - o [Salvadora grahamiae (Mountain Patchnose Snake)]
- Sonora (Ground Snakes)
  - o [Sonora semiannulata (Ground Snake)]
- Storeria
  - o [Storeria dekayi (Brown Snake)]
  - o [Storeria occipitomaculata (Redbelly Snake)]
- Tantilla
  - o [Tantilla atriceps (Mexican Blackhead Snake)]
  - o [Tantilla cucullata (Big Bend Blackhead Snake)]
  - o [Tantilla gracilis (Flathead Snake)]
  - o [Tantilla hobartsmithi (Southwestern Blackhead Snake)]
  - o [Tantilla nigriceps (Plains Blackhead Snake)]
- Thamnophis (Garter and Ribbon Snakes)
  - o [Thamnophis cyrtopsis (Blackneck Garter Snake)]
  - o [Thamnophis marcianus (Checkered Garter Snake)]

    - Thamnophis proximus (Western Ribbon Snake)
    - Thamnophis radix (Plains Garter Snake)
    - Thamnophis sirtalis (Common Garter Snake)
- Trimorphodon
    - Trimorphodon biscutatus (Lyre Snake)
- Tropidoclonion
    - Tropidoclonion lineatum (Lined Snake)
- Virginia (Earth Snakes)
    - Virginia striatula (Rough Earth Snake)
    - Virginia valeriae (Western Earth Snake)

Elapidae

- Micrurus (Coral Snakes)
    - Micrurus tener (Texas Coral Snake) [1]

Viperidae

- Agkistrodon
    - Agkistrodon contortrix (Copperhead) [1]
    - Agkistrodon piscivorus (Cottonmouth) [1]
- Crotalus
    - Crotalus atrox (Western Diamondback Rattlesnake) [1]
    - Crotalus horridus (Timber Rattlesnake) [1]
    - Crotalus lepidus (Rock Rattlesnake) [1]
    - Crotalus molossus (Blacktail Rattlesnake) [1]
    - Crotalus scutulatus (Mojave Rattlesnake) [1]
    - Crotalus viridis (Prairie Rattlesnake) [1]
- Sistrurus
    - Sistrurus catenatus (Massasauga) [1]
    - Sistrurus miliarius (Pigmy Rattlesnake) [1]

[1] indicates venomous snakes

Crocodilians

Alligatoridae

- Alligator
  - Alligator mississippiensis (American Alligator)

CHAPTER VI

SUMMER BIRDS AND MAMMALS
INHABITING THE TRINITY RIVER

by

Charles D. Fisher

with the assistance of:

Linley Risner
Donald Edson
Joe Ackeroyd

TABLE OF CONTENTS

METHODS

The present investigation was carried out principally from mid-May to mid-July, 1972, but some of the data were gathered from February to May, 1972. Emphasis was placed on the middle and lower sections of the Trinity River, from Henderson and Navarro counties southward to the Liberty-Chambers county line.

For the purposes of this study the river was divided into three sections as follows: (1) upper river -- Riverside Drive in Fort Worth downstream to Highway 31 crossing (near Trinidad), total of 154 river miles; (2) middle river -- Highway 31 crossing downstream to Highway 19 crossing (south of Trinity), total of 208 river miles; and (3) lower river -- one mile below Lake Livingston Dam to the Liberty-Chambers county line, total of 126 river miles. All river miles are approximate, and were estimated from the Trinity River Authority watershed map published in April, 1971.

Data were gathered almost entirely from field surveys and censuses. These were conducted principally by boat, but some sites were also visited by vehicle, and on July 10 and 11 an aerial survey by heliocopter was made of the river from Tennessee Colony to Trinity Bay.

Mammals were surveyed by recording all evidence of their presence, such as individuals trapped or sighted, dens, fecal remains, tracks, diggings, and partially eaten food. Trapping was limited to small mammals and was conducted on 12 different nights, each at a different site, by the use of museum special snap traps (similar to ordinary mouse or rat traps) with peanut butter as bait. About 50 traps were set per night. On two occassions bats were collected with a shotgun at dusk.

Data for birds were gathered by field observations and counts. All individuals of certain species (herons, egrets, kingfishers, and others) were counted during a complete traverse of the river by boat. For most birds, however, notes were kept only of their presence or absence and of their relative abundance. Relative abundance was determined, in part, by censuses of all species at more than a dozen selected sites scattered along the whole river. These counts were made for a three or four hour period in the early morning, by a single observer who recorded all birds identified by either sight or song while he walked in a strip generally several hundred yards wide along the river bank. In addition, at four important nesting colonies, herons, egrets, ibises and other species were counted for a two-hour period prior to dark as they returned to the colony, thus giving an estimate of the kinds and numbers of birds utilizing each of these four nesting sites.

The focus of attention throughout this study was on populations inhabiting the water, shoreline, and adjacent bank areas of the river (generally within 1/4 mile of the river). More attention was paid to forest and woodland habitats than to fields, pastures, grasslands, or other open habitats. A majority of all data were therefore obtained from bottomland and hardwood forests.

In addition to the field surveys and censuses, a limited amount of information was gathered through conversations with local residents. Also, information available in the following published lists and species accounts of birds and mammals has been occasionally used in this report to supplement the field data: American Ornithologists Union (1957), Baker (1942; 1949; 1956), Blair, *et al.* (1968), Davis (1966), Griscom, *et al.* (1957), McCarley (1959), Peterson (1960), and Wolfe (1956).

RESULTS

Mammals

Species Present and Their Status

oppossum (*Didelphis marsupialis*): occurs rather commonly all along the river, frequenting a wide variety of habitats; tracks of this species were found irregularly along most of the river.

eastern mole (*Scalopus aquaticus*): apparently not very common, at least in bottomland forests; only rarely were the characteristic raised runways of this species encountered.

short-tailed shrew (*Blarina brevicauda*): probably distributed regularly in forest areas along the middle and lower river, but only one individual was trapped during the current study (on June 8 in northern Liberty County).

least shrew (*Cryptotis parva*): a grassland species, most likely occurring not uncommonly in suitable habitats everywhere within the Trinity watershed, but it was not captured in the present inventory.

eastern pipistrel (Pipistrellus subflavus): primarily a forest species; frequently seen along the middle and lower river at dusk, foraging for insects over the water; specimens were collected at two localities, one in Madison and one in Liberty Counties.

big brown bat (Eptesicus fuscus): although this species is known to range throughout East Texas (Davis, 1966), it was not positively identified during this investigation, and must be relatively uncommon along the Trinity River.

red bat (Lasiurus borealis): probably of regular occurrence in forest areas everywhere along the river; this species was occassionally seen at dusk, and one speciment was collected in Liberty County.

seminole bat (Lasiurus seminolus): another forest species, reaching the western limit of its known range in extreme eastern Texas; not encountered in the present study, but there are specimens from Polk County, and the species probably occurs elsewhere along the lower Trinity River.

northern yellow bat (Lasiurus intermedius floridanus): according to Davis (1966) this is a rare species in Texas, but Barbour and Davis (1967) state that it is one of the most common bats in Florida; southeastern Texas is the western extremity of its known range, and a yellow bat which was collected during this study on June 20 above the mouth of Bedias Creek between Madison and Walker Counties is apparently one of the few specimens for the state.

evening bat (Nycticeius humeralis): not positively identified in the current inventory, but this species was probably one of the bats seen foraging over the river in forested areas at dusk; it is known to be common in parts of East Texas, and Dr. D. J. Schmidly of Texas A&M University (pers. comm.) stated that he has often netted this species along Catfish Creek in Anderson County.

eastern big-eared bat (Plecotus rafinesquei): not encountered in this study, but there are specimens of this bat from northern Polk County, where the first state record was taken in 1966 (Davis, 1966), and it therefore may be of rare occurrence on the lower and middle parts of the river.

Brazilian freetail bat (Tadarida brasiliensis, incl. "cynocephala" and "mexicana"): widespread in Texas and undoubtably breeding along many sections of the river, though no specimens or definite sightings were obtained in the present study.

armadillo (*Dasypus novemcinctus*): one of the most abundant mammals everywhere along the river; frequently seen in the daytime, and tracks and diggings of this species were found at almost every spot visited.

black-tailed jackrabbit (*Lepus californicus*): a western plains species reaching the eastern edge of its range along the upper and middle Trinity River, in non-forest habitats; this species was seen in Anderson County, on the Coffield Prison Farm.

eastern cottontail (*Sylvilagus floridanus*): common along the whole river, principally in upland brushy habitats, but more often encountered on the upper and middle river than along the lower river; largely replaced by the following species in lowland habitats.

swamp rabbit (*Sylvilagus aquaticus*): abundant in bottomland forests along the middle and lower parts of the river; its presence was easily detected not only by the individuals flushed from thickets in the daytime, but also by the many conspicuous piles of fecal pellets found on top of logs.

gray squirrel (*Sciurus carolinensis*): common in floodplain forests and woodlands everywhere along the middle and lower regions of the river, as far upstream as Henderson and Kaufman Counties, but it was most frequently encountered between Anderson and Polk Counties; one of the principal game animals of this part of the state.

fox squirrel (*Sciurus niger*): one of the most abundant mammals along all sections of the river, inhabiting both upland and lowland forests; it was often seen, and leaf nests of this species (and the preceding) were frequently observed; a very popular game species, and of considerable economic importance.

southern flying squirrel (*Glaucomys volans*): resident in woodlands from the upper to the lower regions of the river, but owing to its nocturnal habits it was not often recorded; the high-pitched chattering notes of this species were occasionally heard at night.

thirteen-lined ground squirrel (*Citellus tridecemlineatus*): a grassland species of central and western Texas that has been recorded from Dallas and Navarro Counties (Davis, 1966), but it was not encountered in the current inventory.

plains pocket gopher (*Geomys bursarius*): uncommon to abundant in open upland situations with light soil, the conspicuous mounds of this species were found most often along the middle section of the river, usually well away from the river itself.

hispid pocket mouse (Perognathus hispidus): known to occur along all sections of the river, where it is an occupant of grassy upland habitats on sandy soil; no individuals were trapped during the present study.

beaver (Castor canadensis): a common inhabitant of the river all along its length, from lower Liberty County upriver at least as far as Kaufman County; beaver workings, dens, and tracks were among the mammal signs most frequently observed, although only on one occasion was an actual individual sighted.

long-tailed harvest mouse (Reithrodontomys fulvescens): a rather common rodent in grassy situations, both on upland and lowland sites; specimens were trapped along the river in Freestone, Houston, and Polk Counties.

eastern harvest mouse (Reithrodontomys humulis): reported to occur in deciduous forests as far west as southeastern Texas by Blair, et al. (1968), but this species was not found during the present study, and is apparently uncommon or rare in this part of its range.

deer mouse (Peromyscus maniculatus): a grassland and forest edge species which ranges eastward from central Texas to Dallas and Navarro Counties (Davis, 1966); it might occur locally in favorable habitats on the upper and middle river, but no specimens were obtained during this inventory.

white-footed mouse (Peromyscus leucopus): although this species is known to be a common resident of upland wooded areas throughout the state, it was not trapped during the current investigation.

cotton mouse (Peromyscus gossypinus): the most common small rodent encountered in bottomland forests; specimens were obtained at five different sites, all in Anderson and Liberty Counties.

golden mouse (Peromyscus nuttalli): a relatively uncommon forest rodent which occurs in the southeastern U. S. as far west as East Texas, specimens having been taken from Anderson and Trinity Counties (Davis, 1966); it was not found in this study, and is apparently uncommon or local along the Trinity.

pygmy mouse (Baiomys taylori): known to inhabit the eastern edge of the central Texas prairie region, and the upper coastal plain, but no specimens were obtained during the current investigation; it could occur, in small numbers, almost anywhere along the Trinity River.

northern rice rat (Oryzomys palustris): a rather small native rat inhabiting marshes and grasslands along the lower river, as far upstram as Walker and Trinity Counties (Davis, 1966); it was not encountered in this study.

hispid cotton rat (Sigmodon hispidus): one of the most abundant rodents along most sections of the river, preffering grassland and forest edge habitats, both in upland and low-lying areas; specimens were obtained at two localities (in Anderson and Freestone Counties), and their runways through the grass were observed on several other occasions; a widespread native rodent.

eastern woodrat (Neotoma floridana): nests of this large native rat were found commonly in Anderson County, but were not definitely observed elsewhere; the species is probably locally common along most sections of the river.

house mouse (Mus musculus): a small introduced rodent from the Old World which is widespread in North America; it is usually closely associated with human dwellings, but not infrequently it exists as a feral animal; a specimen was trapped in the present study from a bottomland forest in Anderson County.

roof rat (Rattus rattus): a large Old World rodent which is another commensal of man; widespread throughout most of the state, and an individual was trapped along the river in lower Liberty County during the present investigation.

Norway rat (Rattus norvegicus): known to occur widely in Texas, usually in close association with man; this introduced European species was not found in the present study.

nutria (Myocastor coypus): introduced from South America into the southern U. S., and now a common mammal in most of eastern Texas; this is a large semi-aquatic rodent which prefers quiet waters of ponds and marshes, or sluggish streams; it was found along the river only at two localities, one in Anderson County (where 6 individuals were seen together on the river bank) and one in Liberty County (where fecal pellets were discovered on the shore); poorly defined tracks suspected of belonging to this species were found on one or two occasions.

coyote (Canis latrans): a relatively common resident along most sections of the river, but not generally inhabiting the more extensive forest regions; tracks and "scats" of coyotes were found most commonly on the middle river, and several individuals were heard one night in Navarro County from a campsite across the river in Henderson County; almost all references to "wolves" by native East Texans pertain to this species.

red wolf (Canis niger): formerly ranged throughout East Texas, but now apparently confined to the upper coastal plain, where it is uncommon; it is probable that individuals of this species occasionally wander northward along the Trinity River into Liberty County; no positive evidence of this large canine was found during the present study.

red fox (Vulpes fulva): status uncertain; according to Blair (1966) this native American fox has been introduced at several localities in East Texas, but no certain signs of its presence were observed in this study.

gray fox (Urocyon cinereoargenteus): uncommon to common along the whole river, perhaps being most numerous in wooded areas of the middle river; tracks or scats of this species were identified at several localities.

ringtail (Bassariscus astutus): reported to occur fairly commonly along the upper parts of the river, at least as far south as Anderson County (Walt Daniel, pers. comm.); principally a semi-arid species of the Southwest; it was not encountered in the current inventory.

raccoon (Procyon lotor): common to abundant everywhere along the river; this species habitually forages along the shore, and its tracks were found more often that those of any other species.

long-tailed weasel (Mustela frenata): probably of rare occurrence in upland situations from the upper to the lower parts of the river, but no signs of this mammal were found in the current investigation.

mink (Mustela vison): occurs along all sections of the river, but it is apparently most numerous in wooded areas of the middle and lower river; tracks of this small carnivore were only occasionally identified along the river bank, but trappers reported it as common.

striped skunk (Mephitis mephitis): generally common on the middle and upper river, becoming less numerous along the lower river; prefers farmlands with scattered patches of woods; tracks of this species were regularly found, and not infrequently dead animals were seen along the highway.

spotted skunk (Spilogale putorius): this wide-ranging species is apparently only locally common in eastern Texas, and it was not recorded in the present inventory; according to McCarley (1959) it is present in open grassland situations interspersed with woodlands in Leon and Freestone Counties.

American goldfinch (Spinus tristis): one record, a pair of birds in breeding plumage seen along the river in Anderson County on June 29.

✓ lark sparrow (Chondestes grammacus): fairly common on the upper part of the river in open fields and pastures and along roadsides; less numerous and somewhat local on the middle river and not found south of Polk County.

✓ grasshopper sparrow (Ammodramus savannarum): rather rare and local in open grassland habitats on the upper river, south at least as far as Anderson County.

Bachman's sparrow (Aimophila aestivalis): known to be a local summer resident in East Texas in old fields and open pine woodlands; not recorded in the current inventory, but a singing male was heard in Polk County on June 5, 1971, at a site 4 miles west of Moscow.

chipping sparrow (Spizella passerina): breeds locally in open pine forests in East Texas; recorded only from Polk County in this study.

field sparrow (Spizella pusilla): only one record, a bird seen in Freestone County on July 3, across the river from Coffield Prison Farm; inhabits old fields and weedy pastures.

Nesting Sites and Censuses of Herons, Egrets Ibises, and Associated Species

Certain species of large wading and water birds characteristically nest gregariously in mixed colonies or "heronries." In East Texas these nesting colonies are almost always situated in the middle of a small to large swamp where there is a dense growth of shrubs (usually buttonbush, Cephalanthus occidentalis); often there are also scattered tall trees present, such as cypress (Taxodium distichum) and tupelo gum (Nyssa aquatica). Nests are built in the shrubs and trees at all heights above the water. The number of birds nesting in suitable swamps is frequently limited by the number of nest sites available. Oxbow lakes and swamps with only open water in the middle, or without small woody vegetation (i.e., shrubs), are not usually chosen as nesting sites, at least by the two species--cattle egret and little blue heron--which characteristically make up the majority of individuals in the large East Texas colonies. Therefore, nesting colonies tend to be rather widely scattered owing to the relative unavailability of preferred sites. In the present inventory only three large heronries and one smaller colony were located and censused. Another relatively small colony was located but not censused. There are undoubtedly other important nesting sites along the Trinity River and small heronries with only a few hundred birds or less are probably of regular occurrence. All of the heronries censused in the present inventory are within 5 miles of the river.

Census results for the four colonies are shown in Table 33 . It should be pointed out that these figures underestimate the total populations utilizing the sites for breeding or nesting, since all the individuals in a colony cannot be expected to have passed over the four observers during the two-hour census periods. Some individuals, particularly of the anhinga, green heron, and two species of night herons, probably forage in or near the swamp utilized for nesting, and would thus not be counted by observers stationed away from the swamp. Night herons were counted as they left the colony, rather than as they returned. The figures listed are for adult birds only, as well as could be determined, but it cannot be assumed that they all necessarily represent breeding birds, since some non-breeding individuals could utilize the colony only for roosting purposes. The wood ibises were almost certainly post-breeding visitors to the two lower river colonies and this is probably also true of the 4 spoonbills at the Old River heronry.

The cattle egret was always the most numerous species present, often overwhelmingly so. On the middle river the little blue heron was the second most abundant species, but on the extreme lower portion of the river the white ibis ranked as the second most numerous species. These three species comprised from 87-97 percent of all individuals in all four colonies. The tremendous increase and spread of cattle egrets in Texas since its first occurrence in the state in 1955 (Wolfe, 1956) is of major ornithological significance.

Use of the Trinity River for Foraging by Large Wading and Other Birds

A dozen or so relatively common breeding birds (Table 34) directly utilize the shore and water of the Trinity River for obtaining food. These species as a whole feed primarily on small aquatic and shoreline invertebrates and small to medium-sized fish. One species (the wood duck) consumes primarily aquatic vegetation, as well as

Table 33. Estimates of breeding populations of herons, egrets, ibises and other birds at known nesting colonies along the Trinity River[a]

Species	Total Individuals (left) and Percent of Total Population (right)							
	site 1[b]		site 2[c]		site 3[d]		site 4[e]	
anhinga	24	0.2	26	1.1	10	1.6	100*	1.5
great blue heron	9	0.1	8	0.3	5	0.8	50*	0.8
green heron	10	0.1	14	0.6	2	0.3	1	0.0
little blue heron	995	10.4	340	14.5	78	12.8	335*	5.1
cattle egret	8389	87.9	1882	80.2	268	44.1	4219	64.0
common egret	50	0.5	36	1.5	26	4.3	61	0.9
snowy egret	21	0.2	13	0.5	1	0.2	5	0.1
Louisiana heron	0	0.0	0	0.0	1	0.2	266	4.0
b-c night heron	9	0.1	3	0.1	0	0.0	3	0.0
y-c night heron	27	0.3	17	0.7	28	4.6	17*	0.3
wood ibis	0	0.0	0	0.0	3	0.5	7	0.1
white ibis	10	0.1	9	0.4	186	30.6	1526	23.1
roseate spoonbill	0	0.0	0	0.0	0	0.0	4	0.1
Total	9544	99.9	2348	99.9	608	100.0	6594	100.0

Total	9544	99.9	2348	99.9	608	100.0	6594	100.0

Table 33. Continued

[a]Each census was conducted bysstationing 4 observers roughly in a circle around the resting colony, at distances of 1/2-3 miles away from the swamp where it was situated; birds were counted as they returned to the colony during the 2 hour period prior to dark. The figures listed are for adult birds only.

[b]Sand Pond heronry (Anderson County, 3 miles NW of Tennessee Colony); July 4, 1972.

[c]Goodrich heronry (lower Polk County, 1 1/2 miles SE of Goodrich); June 21, 1972.

[d]Tanner Bayou heronry (upper Liberty County, 1 mile S of Highway 162 bridge); July 12, 1972.

[e]Old River heronry (lower Liberty County, 2 miles NE of Old River); July 13, 1972.

*These figures were obtained by counting birds in the colony itself early on the morning of July 27, and all are somewhat higher than the figures for the evening count on July 13.

Table 34. Summer census of avian species utilizing the shores and water of the Trinity River for feeding[a]

Species	Total individuals (left) and birds per river mile (right)											
	section 1[b]		section 2[c]		section 3[d]		section 4[e]		section 5[f]		section 6[g]	
anhinga	0	0.00	0	0.00	0	0.00	13	0.27	35	0.60	14	0.23
great blue heron	11	0.18	25	0.32	20	0.24	4	0.08	22	0.38	11	0.18
green heron	4	0.07	3	0.04	16	0.19	15	0.31	15	0.26	4	0.07
little blue heron	46	0.77	70	0.90	100	1.20	14	0.29	40	0.69	13	0.21
cattle egret	5	0.08	4	0.05	2	0.02	4	0.08	5	0.09	7	0.11
common egret	1	0.02	0	0.00	5	0.06	16	0.33	7	0.12	11	0.18
snowy egret	1	0.02	2	0.03	9	0.11	7	0.14	32	0.55	13	0.21
y-c night heron	3	0.05	8	0.10	13	0.16	2	0.04	6	0.10	6	0.10
wood duck	9	0.15	7	0.09	4	0.05	0	0.00	2	0.03	3	0.05
osprey	0	0.00	0	0.00	0	0.00	0	0.00	1	0.02	1	0:02
killdeer	26	0.43	30	0.38	13	0.16	1	0.02	5	0.09	5	0.08
belted kingfisher	1	0.02	3	0.04	2	0.02	5	0.10	18	0.31	6	0.10

Table 34. Continued

[a]river censused by proceeding downstream in a boat at an average speed of approximately 10-12 mph; census dates June 8-July 9, 1972.

[b]Highway 34 to Highway 31 (60 river miles).

[c]Highway 31 to Highway 79/84 (78 river miles).

[d]Highway 79/84 to Highway 21 (83 river miles).

[e]Highway 21 to Highway 19 (48 river miles).

[f]One mile below Lake Livingston dam to Highway 162 (58 river miles).

[g]Highway 162 to 3 miles above Interstate Highway 10 (61 river miles).

seeds and nuts obtained on shore. Due to differences in size and kind of food taken, manner of captureing food, and particular part of the shore or river utilized, these species inhabit different foraging niches, and successfully divide up the available food resources among themselves. This has been indicated at the family level in Table 35, which in addition to the species listed in Table 34, also includes data for the rough-winged swallow (family Hirundinidae) and three species of hawks (red-tailed hawk, red-shouldered hawk, and Mississippi kite, all in the family Accipitridae); the anhinga is in the family Anhingidae, all herons and egrets in the Ardeidae, the wood duck in the Anatidae, the osprey in the Pandionidae, the killdeer in the Charadriidae, and the kingfisher in the Alcedinidae.

Since a given point on the river was censused only at a particular instant of time, it is obvious that the data in Tables 34 and 35 do not represent the total numbers of individuals utilizing the river for foraging during the summer (or even during a day), but merely allow very crude comparisons of one section of the river with another section. In this regard the following facts seem evident: (1) there are few striking differences between the upper, middle, and lower sections of the river (though it should be remembered that only the lower part of the upper river was censused by boat); (2) in comparing birds per river mile, rough-winged swallows were least abundant but killdeer and wood ducks were most abundant on the upper river, red-tailed and red-shouldered hawks were most abundant on the middle river, and anhingas and kingfishers occurred most frequently along the lower river; (3) at the family level, herons and egrets were fairly uniformly distributed along all sections of the river, though they were slightly less numerous on the upper river; (cattle egrets were counted only when they were seen feeding on the shore near the water, with or without the presence of cattle).

The above figures reflect many factors, including time of day of the census, stage of breeding season, food abundance and quality, availability of suitable mudbanks and sandbars, nearness to breeding sites, and water level of the river. The data must, therefore, be interpreted very cautiously. It is suspected, for instance, that the somewhat larger number of wood ducks per mile on the upper river is in part because adults were on the river with young at the time of year (early July) that this part of the river was censused, and also because fewer suitable habitats for this species are available away from the river in this area than on the middle and lower parts of the river.

Table 35. Relative use of the Trinity River for foraging by various families of birds during the breeding season[a]

Family[b]	Feeding Niche	Total individuals (left) and birds per river mile (right)					
		upper river[c]		middle river[d]		lower river[e]	
Anhingidae (1)	deep water fish	0	0.00	13	0.06	49	0.39
Ardeidae (7)	shoreline and shallow water invertebrates and fish	71	1.18	339	1.63	192	1.52
Anatidae (1)	seeds, nuts, aquatic plants	9	0.15	11	0.05	5	0.04
Accipitridae (3)	small terrestrial vertebrates and large insects	7	0.12	50	0.24	19	0.15
Pandionidae (1)	medium-sized fish near the surface	0	0.00	0	0.00	2	0.02
Charadriidae (1)	small shoreline invertebrates	26	0.43	44	0.21	10	0.08
Alcedinidae (1)	small fish near the surface	1	0.02	10	0.05	24	0.19
Hirundinidae (1)	aerial insects	1	0.02	65	0.31	38	0.30

[a]River censused by proceeding downstream in a boat at an average speed of approximately 10-12 mpg; census dates June 8-July 9, 1972.
[b]Parentheses indicate the number of species involved in each family.
[c]Highway 34 to Highway 31 (60 river miles). [d]Highway 31 to Highway 19 (208 river miles).
[e]One mile below Lake Livingston dam to 3 miles above Interstate Highway 10 (126 river miles).

DISCUSSION

Rare, Endangered, and Endemic Species

black bear (Ursus americanus): this species was once widespread in Texas, but now is found only in small numbers in the western mountains (Davis, 1966). According to Baker (1956) bears persisted in East Texas at least until the 1930's, and there are a few later reports from Tyler, Polk, Angelina, and Nacogdoches Counties. In the current survey no evidence of bears was found and they were not reported to the investigators by any local resident. It is therefore very unlikely that this species now exists anywhere along the Trinity River.

river otter (Lutra canadensis): although no conclusive signs of river otters were found during this inventory, it was reported as occurring on the lower Trinity River in Liberty County by two residents who were interviewed, and Davis (1966) says that it still occurs locally in East Texas. A specimen from the Attoyac River in Nacogdoches County was brought to this investigator in 1970. This semi-aquatic carnivorous mammal must therefore be considered a rare inhabitant of at least the lower part of the river.

red wolf (Canis niger): the red wolf formerly ranged widely over East and Central Texas, as far north as the Red River (Davis, 1966), but recent specimens from Texas are all from the upper coastal region, centering in Chambers County. It is difficult to gather reliable information because this species is often confused with the coyote, with which it apparently readily interbreeds. Hybrid animals add to the problem of identification (see McCarley 1959). It is this investigators opinion that red wolves could and probably do occasionally wander northward along the lower part of the Trinity River in Liberty County, but conclusive evidence is presently lacking. This species prefers open areas with adequate cover rather than extensive forests.

cougar or mountain lion (Felis concolor): cougars are known to occur with certainty in Texas today only in the more remote parts of South and West Texas, where their numbers are apparently dwindling. This species once occurred throughout the state, and there are still frequent unconfirmed reports from many parts of East Texas. Several persons who were interviewed in Liberty County and one in Anderson County insisted that they had seen mountain lions or their tracks recently. However, in the absence of any convincing evidence it is considered highly improbable that this species inhabits any area along the Trinity River today. Nevertheless, there are some habitats, such as the Tanner Bayou area, which could conceiveably support a pair of these animals. According to Baker (1956) the last reliable report from East Texas was from Angelina County in 1927.

wood ibis (Mycteria americana): the present breeding range of this speices in the United States is apparently restricted at least on a regular basis, to Florida (A.O.U., 1957). However, wood ibises wander widely in mid- and late summer, reaching coastal Texas by June and then continuing inland in many localities (Peterson, 1960; Wolfe, 1956). This investigator has found them to be of regular occurrence, in small numbers or groups of up to 20 individuals all along the Trinity River, first appearing in mid-June. Birds forage around the edges of marshes, swamps and lakes, but apparently only very rarely on the shore of the river itself.

roseate spoonbill (Ajaia ajaja): spoonbills nest very locally along the central and upper coast of Texas, including Chambers County, and at scattered locations elsewhere around the Gulf to Florida. It is possible that a few pairs nest in the Old River heronry (on the Trinity River just above the Liberty-Chambers county line, see Table 33). After the breeding season some individuals wander inland, and can be expected almost anywhere along the river, as far northward as Dallas. This investigator recorded a single individual along the river in northwestern Henderson County on June 27.

Mississippi kite (Ictinia misisippiensis): although this species is a locally common breeding bird in parts of the Texas Panhandle and North-central Texas, it was not known to occur as a summer resident anywhere in East Texas prior to the present investigation. A total of 13 individuals (7 adults, 5 sub-adults, and 1 bird of undetermined age) were recorded at 8 different sites along the lower Trinity River, all in Liberty County except for one site between Polk and San Jacinto Counties (approximately 2 miles below Lake Livingston dam, where 2 adults and 1 sub-adult were seen). Although sub-adults (i.e., about 1 year old) may not have been breeding, it is probable that adults were, but no nests were found. Mississippi kites prefer open wooded areas or scattered trees near water. They are known to breed locally from the southeastern part of the Great Plains across the southern part of the United States to the Atlantic coast.

osprey (Pandion haliaetus): this species is extremely widespread, breeding throughout much of North America and elsewhere in both the Old and New Worlds. However, it is nowhere common, and North American populations have declined sharply in the past 20 years. Wolfe (1956) states that no definite nesting records are known for Texas, although he cites a report by Simmons in 1925 which claimed the species was a permanent resident along the coast. It is suspected that most summer records of ospreys from Texas are of non-breeding birds, which is likely true of the two individuals observed during this study on the lower Trinity River in June. The species is known from the state promarily as a migrant and winter resident, occurring along the coast and on the larger lakes and rivers. The osprey is a fish-eating species, and it is thought that its recent decline is a result largely of chlorinated hydrocarbons (primarily DDT) in its body tissues.

red-cockaded woodpecker (Dendrocopus borealis): because of its dependence on mature pine stands (see Lay and Russell, 1970), this is a very local species in East Texas, and elsewhere throughout its range across the southeastern United States. Rarely are suitable habitats found very near the Trinity River, and the only population of which this investigator is aware in the general area of the present inventory is one on the north side of Lake Livingston in the Brushy Creek area of Trinity County (Dan Lay, pers. comm.).

ivory-billed woodpecker (Campephilus principalis): although Wolfe (1956) considered this species extinct in Texas, there have been numerous unconfirmed sightings in the Big Thicket area of East Texas during the last ten years (unpublished report by Fred Collins, Texas A&M University), the most publicized being those of John Dennis (Dennis, 1967). Owing to the lack of evidence, many orthinologists have been unwilling to accept any of the recent reports as authentic, and some such as Dr. Keith Arnold of Texas A&M University (pers. comm.) and Dr. J. T. Tanner at the University of Tennessee (Moser, 1972) are convinced the species does not inhabit any site in Texas today. The ivory-billed woodpecker, if not already extinct, must certainly be considered on the verge of extinction, not only in Texas but everywhere throughout its former range in the southeastern United States and Cuba (see Tanner, 1942; Dennis, 1948).

In the present investigation a large woodpecker was seen and sketched by Lin Risner on July 12 as it flew along the west bank of the river about 2 miles below Highway 162 in the Tanner Bayou area of Liberty County. There is no doubt that the sketch drawn is that of an ivory-billed woodpecker, the upper wing pattern being unmistakable. If it is to be argued that Mr. Risner did not see an ivory-billed woodpecker, then it would have to be concluded that either: (1) he sketched something he did not see at all, or (2) his sketch is not an accurate representation of what he saw. My personal knowledge of Mr. Risner's character and integrity, and of his keen ability as a field observer, leads me to conclude that he did, in fact, see an ivory-billed woodpecker. The area is a relatively undisturbed bottomland forest of some 13,000 acres.

Species of Economic Importance

Game animals

The white-tailed deer is an extremely popular and important game species along most of the Trinity River, where it reaches its largest population densities in bottomland hardwood forests (see Collins, 1961; Lay, 1965; Segelquist and Green, 1968; Stransky and Halls, 1962). Many landowners lease their property for deer hunting in the fall and there are several large hunting clubs, such as the Arizona Creek Wildlife Club in Liberty County with approximately 100,000 acres and about 2,000 members (M. J. Cain, pers. comm.). Sportsmen interviewed often said that deer hunting along the middle regions of the river was among the best anywhere in the state, and this was also the opinion of Mr. Walt Daniel, the resident game biologist in Fairfield (pers. comm.). Other mammals which are extensively hunted for sport are the gray and fox squirrels, and to a lesser extent the swamp and cottontail rabbits. Raccoon and fox hunting are also very popular sports along the Trinity River. These animals, mostly inhabitants of forested areas, provide many hours of recreation and bring a considerable amount of revenue into the region.

The Trinity watershed is one of the most valuable areas in East Texas for breeding wood ducks. Although these birds were not very often seen on the river itself, they nest in moderate densities on the wooded swamps, sloughs, and oxbow lakes on the floodplain. Sixty-four wood ducks were counted flying over the river at dusk on July 13 from an observation point near Moss Bluff in Liberty County, and on July 12 at Gaylor Lake in the Tanner Bayou area of Liberty County a total of 31 birds were counted in the hour before dark. Several broods of half-grown young wood ducks were seen on the upper and middle sections of the river in early July, always accompanied by one or both parents.

Although no data were gathered during this investigation during the winter months, this investigator was informed by numerous residents, and by Walt Daniel of Fairfield, that the same areas utilized for breeding by wood ducks are frequented by many hundreds of wintering waterfowl from October through March. These birds are extensively hunted and their popularity among hunters ranks with that of the white-tailed deer. The site of the Old River heronry (Table) is a 1,700 acre duck hunting preserve. This very large swamp is located about one mile west of the river and two miles north of the Liberty-Chambers county line.

Fur-bearing animals

Beavers are more abundant in the Trinity River watershed (to the knowledge of this investigator) than they are anywhere else in the state of Texas. Dan Lay (pers. comm.) stated that populations along the Trinity River were introduced there from West Texas populations in the late 1930's and early 1940's after native beavers had been virtually exterminated from East Texas in the early part of the century. Owing to protection given them by law this species made a remarkable comeback along the Trinity River, to the point where they are now sometimes considered a nuisance and a pest. Although they have valuable pelts, and trapping permits can be obtained from the Texas Parks and Wildlife Department, there appears to be little interest in commercial trapping of beavers along the river today. Likewise, there is an apparent lack of interest in exploiting the mink, another relatively common fur-bearing mammal inhabiting the Trinity River.

A third species, the introduced nutria from South America, also has a pelt of potential commercial value, but this investigator is not aware of any nutrias being trapped for their fur. Although not common on the river itself, the nutria was rather frequently encountered in marshes or lakes near the river, and on some of the larger slow-moving tributary streams such as Redmond Creek in lower Liberty County. At times nutria populations can build up in a marsh, lake, canal, or irrigation ditch to the point where the animals become a major pest by eating all of the aquatic vegetation, or even crops and pine seedlings (Evans, 1970; Atwood, 1950).

Sites of Particular Ecological Importance

From an ecological viewpoint there are many valuable areas along the Trinity River. The most extensive remaining forest areas have been outlined by Dr. E. S. Nixon in the botanical section of this overall report. All of these sites are very important for wildlife.

These include: (1) the forest area between the old and new channels of the East Fork of the Trinity River in Kaufman County, at their confluence with the Trinity River; (2) the Bruce Smith Ranch on the east side of the river in Henderson County, southwest of Tool (in the Sanders Creek general area); (3) the east side of the river in Anderson County in the general vicinity of Big Lake, several miles above Highway 84 crossing; (4) the south side of the river in Walker County in the Black Creek/White Oak Creek area; (5) the north side of the river in Walker County on the Earl Moore Ranch in the Horseshoe Lake area; (6) the south and west side of the river in San Jacinto County south of FM 1127 in the Davison Bayou/Coley Creek area; (7) most of the west side of the river in Liberty County between the New River Lakes Development and Sam Houston Lakes Development (approximately the middle region of the river between Highways 105 and 162); (8) the Tanner Bayou area on the west side of the river in Liberty County between Highway 162 and Capers Ridge; and (9) a large forested and swampy area on the west side of the river in Liberty County across from Moss Bluff, generally from about 1-1/2 miles north of the county line north to the Harrison and Timber Lake subdivisions.

Although the above sites are considered to be the best wildlife areas along the river at the present time, it should be emphasized that numerous other sites are also highly valuable, including all nesting colonies of herons and egrets (see Table 33). In Liberty County where most of the river is extensively forested on both sides it is difficult to single out specific sites as being more important than others. However, the present survey of the river indicates that the Tanner Bayou area is almost certainly the most significant and valuable ecological area situated anywhere along the Trinity River today. Every effort should be made to preserve it. Currently, most of the approximately 13,000 acres of forest in this area is owned by the Kirby Lumber Company, and the area is leased for both hunting and grazing. However, because of the inaccessibility by road to much of the area, it remains relatively little disturbed by man. It is possible that one or more ivory-billed woodpeckers may inhabit this area.

CONCLUSIONS

The Trinity River lies on the western edge of the Austroriparian biotic province (Dice, 1943; Blair, 1950), and its avian and mammalian faunas are, in general, typical of those of the whole southeastern United States.

Its position places the river in an important ecological region where eastern forest species come in contact with species characteristic of the grasslands of the Great Plains. The Trinity River is thus in a transition zone where many forest birds and mammals reach the western limit of their range and some prairie species reach the eastern extension of their distribution. This mixing of fauna is most evident on the upper part of the river. Usually the plains species inhabit upland situations and eastern species lowland habitats. Forest birds such as the Swainson's and hooded warblers were not found farther up the river than Anderson County, and species such as the field sparrow and western kingbird were not encountered farther south than Freestone and Navarro counties respectively.

There is an abundance and varied bird and mammal fauna inhabiting the Trinity River Watershed. The diversity is greatest in the bottomland and floodplain forests adjacent to the river, and these habitats are of considerable importance in the overall ecosystem of the river as are the many swamps, sloughs, and oxbow lakes lying back from the river along most of its length. These areas provide breeding and foraging sites for many important game animals, and several very large nesting colonies of herons and egrets are situated within a few miles of the river. The river itself is utilized extensively for foraging by many species of large wading birds, and also by anhingas, wood ducks, kingfishers, small shore birds, and an occasional osprey, the latter one of the endangered North American birds. Mississippi kites apparently breed along the lower river and nowhere else in East Texas.

Beavers may be more numerous on the Trinity River than anywhere else in the state, and some of the finest deer hunting in Texas is available in some of the forested areas along the river. The trees and woodlands along the river are available to many kinds of small songbirds during spring and fall migrations, and waterfowl which nest in northern North America can utilize the numerous swamps and lakes on the floodplain during the non-breeding season. The Tanner Bayou area may be one of the few remaining sites anywhere in the United States where the ivory-billed woodpecker still persists.

APPENDIX B

CITY OF DALLAS

April 2, 1997

Dear Council Coordinator:

The City of Dallas is committed to providing $ 50,000 to match the grant request for the proposal entitled "The Great Trinity River Forest Park." Following are the details pertaining to our contribution:

The I-20 gateway property is a tract of 208 acres of land that is vital to the development of the Great Trinity River Forest Park.

The property is appraised at $ 437,000.

The Texas Park and Wildlife Department has committed to make available $ 337,000 toward the purchase of this land. (Please see enclosed letter of commitment)
The City of Dallas is committing $50,000.
NAWCA Grant (if approved) $ 50,000.

This purchase of this tract of land stresses the preservation of the wetlands and forest through acquisition.

Sincerely,

John L. Ware
City Manager

OFFICE OF THE CITY MANAGER CITY HALL DALLAS, TEXAS 75201 TELEPHONE 214/670-3302

TEXAS
PARKS AND WILDLIFE DEPARTMENT
4200 Smith School Road • Austin, Texas 78744 • 512-389-4800

March 24, 1997

Mr. Peter Vargas
Director, Trinity River Project
320 Jefferson, Room 101
Dallas, Texas 75203

Dear Mr. Vargas:

As you know, the Trust for Public Land has an option to purchase a 208 acre tract of Trinity River bottomland hardwood habitat, which is a key component to the proposed Great Trinity Forest Park. The Parks and Wildlife`Department has $337,000 remaining from funds previously appropriated for the Trinity River State Park which we intend to make available for acquisition of the 208 acre tract if the City can provide the remaining $100,000 needed for the purchase.

The Parks and Wildlife Department is pleased to play a part of the conservation of this significant natural and cultural resource.

Sincerely,

Mike Herring

Mike Herring
Director, Land Conservation

APPENDIX C

Project budget to acquire one tract (208 acres) of land for "The Great Trinity River Forest Park"

CATEGORY	NAWCA GRANT FUNDS	PARTNER FUNDS	EXPENSE PER CATEGORY
Acquisition	$ 50,000	$ 427,000	$ 437,000

Great Trinity Forest Management Plan

Wildlife Management

Annotated Checklist of Recent Land Mammals of Texas, 1998

OCCASIONAL PAPERS

Museum of Texas Tech University

NUMBER 182 — 16 November 1998

ANNOTATED CHECKLIST OF RECENT LAND MAMMALS OF TEXAS, 1998

RICHARD W. MANNING AND CLYDE JONES

Checklists are in demand by biologists, students, researchers, and environmentally concerned individuals. In order for them to be most useful, they must be current. This checklist is an updated version of two previous lists of free-ranging Texas mammals (Jones et al., 1988*a*; Jones and Jones, 1992). This checklist includes a phylogenetic listing of taxa, by order, family, and genus. Within genera, species and recognized subspecies are listed alphabetically. Species marked with an asterisk (*) are exotic species introduced from outside the United States. The approximate known geographic distribution within the state of Texas is reported for each mammal and pertinent comments and /or citations about that taxon may be included. Many accounts are unchanged from earlier editions of the checklist as Jones and Jones (1992) wrote them.

Several taxonomic and nomenclaturial changes have occurred since the last checklist was published; note especially Wilson and Reeder (1993) on world mammals, Jones et al. (1997) on North American mammals, and Davis and Schmidly (1994) on Texas mammals. In addition, other major studies on Texas mammals were completed which provide valuable information. These studies include the following geographic areas: the Llano Estacado (Choate, 1997), the Edwards Plateau (Goetze, 1998, Goetze et al., 1996), Big Bend Ranch State Park (Yancey, 1997), southern Kansan Biotic Province (Choate et al., 1992), the Lake Meredith area (Yancey et al., 1998), and the Justiceburg area (Yancey et al., 1996*b*). Many citations from the earlier lists are repeated here. Our goal was to make this checklist as complete as possible through the end of 1997. For some additional information on the mammals of Texas, visit the homepage (http://www.nsrl.ttu.edu) of the Natural Science Research Laboratory of the Museum of Texas Tech University.

ORDER DIDELPHIMORPHIA— OPOSSUMS

Family Didelphidae
(opossums)

Didelphis virginiana (Virginia opossum).— Occurs throughout most of Texas except in relatively xeric areas in western part of state (parts of Llano Estacado and most of Trans-Pecos). The subspecies are *D. v. virginiana* Kerr, 1792, in northern and central Texas and *D. v. pigra* Bangs, 1898, in the south and southeast. We follow Marshall et al. (1990) in use of the ordinal name Didelphimorphia. Hollander and Hogan (1992) reported a specimen collected in Jeff Davis County, in the Trans-Pecos.

ORDER INSECTIVORA—INSECTIVORES

Family Soricidae
(shrews)

Blarina carolinensis (southern short-tailed shrew).— Known from eastern fourth of state. The subspecies are *B. c. carolinensis* (Bachman, 1837) in the northern part of the range in Texas (south at least to Nacogdoches County) and *B. c. minima* Lowery, 1943, in the south.

Blarina hylophaga (Elliot's short-tailed shrew).— Recorded only from Montague County and from Aransas National Wildlife Refuge, Aransas County. The subspecies are *B. h. hylophaga* Elliot, 1899, and *B. h. plumbea* Davis, 1941, respectively. The systematics of shrews of the genus *Blarina* have not been entirely resolved to date, differences among the three known species having been based primarily on mensural data and karyology. Pending further study, we follow Jones et al. (1984) in referring these apparently isolated populations to *B. hylophaga.* Stangl and Carr (1997) discuss the status of species in northern Texas and southern Oklahoma.

Cryptotis parva (least shrew).— Occurs in eastern and central parts of state, west in northern Panhandle to New Mexico border and to Val Verde County along Rio Grande. The subspecies are *C. p. parva* (Say, 1823) throughout most of the distribution in Texas and *C. p. berlandieri* (Baird, 1858) on the Rio Grande Plain. Dowler and Boyd (1996) reported specimens from Tom Green County, a range extension in west-central Texas.

Notiosorex crawfordi (desert shrew).— Recorded from western two thirds of state, east at least to Archer and Wichita counties in north, and to Gulf Coast southwardly. The subspecies is *N. c. crawfordi* (Coues, 1877).

Family Talpidae
(moles)

Scalopus aquaticus (eastern mole).— Presently known from approximately eastern two-thirds of state, west along Canadian River in Panhandle, possibly to New Mexican border, and to eastern edge of Llano Estacado (Choate, 1990), and southwardly to apparently isolated population in Presidio County. Five subspecies currently are thought to occur in Texas: *S. a. aereus* (Bangs, 1896) in the extreme east and also the Panhandle region; *S. a. alleni* Baker, 1951, in south-central Texas; *S. a. cryptus* Davis, 1942, in the east-central part of the state; *S. a. inflatus* Jackson, 1914, on the southern part of the Rio Grande Plain; and *S. a. texanus* (J. A. Allen, 1891), an enigmatic race known from Presidio County by a single specimen taken in 1887, and far removed from other known populations except for one individual from the Sierra del Carmens, across the Rio Grande in adjacent Coahuila. Yancey et al. (1995*a*:105) collected a mole, "the first from the escarpment breaks of the Rolling Plains in Garza County."

ORDER CHIROPTERA—BATS

Family Mormoopidae
(mormoopid bats)

Mormoops megalophylla (ghost-faced bat).— Known from Apache Mountains, Culberson County, southern Trans-Pecos, southern part of Edwards Plateau, and southern Texas (Cameron and Hidalgo counties); inhabits caves along extreme southern edge of Edwards Plateau in winter and is summer resident of Trans-Pecos. The subspecies is *M. m. megalophylla* (Peters, 1864).

Family Phyllostomidae
(leaf-nosed bats)

Leptonycteris nivalis (Mexican long-nosed bat).— Recorded only from Big Bend area in southern Trans-Pecos region (Brewster and Presidio counties); probably resident there only in warm weather. *Leptonycteris nivalis* (Saussure, 1860) is a monotypic species.

Choeronycteris mexicana (Mexican long-tongued bat).— Known by photographs of a single individual and observations of others from Santa Ana National Wildlife Refuge, Hidalgo County (Schmidly, 1991). No specimens from Texas yet have been preserved. These records probably represent accidental northward occurrences of this bat. *Choeronycteris mexicana* Tschudi, 1844, is a monotypic species.

Diphylla ecaudata (hairy-legged vampire).— Known only by single extralimital record from Val Verde County. *Diphylla ecaudata* Spix, 1823, is a monotypic species.

Family Vespertilionidae
(vespertilionid bats)

Myotis austroriparius (southeastern myotis).— Known range includes extreme eastern Texas, from Bowie County southward to Harris and Orange counties (Schmidly, 1991). The subspecies is *M. a. austroriparius* (Rhoads, 1897). Walker et al. (1996) reported southeastern myotis from three counties (Leon, Freestone and Walker), all west of the previously known distribution in Texas.

Myotis californicus (California myotis).— Recorded in Texas only from Trans-Pecos region and from one specimen (Choate and Killibrew, 1991) from Canyon, Randall County, near the breaks of Llano Estacado. Other specimens have been reported (Choate et al., 1990) from along the edge of the Llano in adjacent New Mexico. The subspecies is *M. c. californicus* (Audubon and Bachman, 1842).

Myotis ciliolabrum (western small-footed myotis).— Saxicolous species known from western half of Trans-Pecos and from Armstrong and Randall counties in Panhandle (Schmidly, 1991). The subspecies is *M. c. ciliolabrum* (Merriam, 1886).

Myotis lucifugus (little brown myotis).— Reported from Texas on basis of single specimen from Fort Hancock, Hudspeth County. Schmidly (1991) opined that "it is doubtful that a resident population of this bat occurs in Texas." The subspecies is *M. l. occultus* Hollister, 1909.

Myotis septentrionalis (northern myotis).— A specimen from Winter Haven, Dimmit County, in the National Museum of Natural History is only known record from state; obtained almost half a century ago, this individual extends known range of northern myotis more than 500 miles southward from southwestern Arkansas and eastern Oklahoma; present status in Texas unknown. *Myotis septentrionalis* (Trouessart, 1897) is a monotypic species.

Myotis thysanodes (fringed myotis).— Reported from much of Trans-Pecos region and from Crosby County at eastern edge of Llano Estacado. The subspecies is *M. t. thysanodes* Miller, 1897.

Myotis velifer (cave myotis).— Occurs over most of western part of state, east at least to Wichita County in the north and to (north to south) McLennan, Bastrop, Kleberg, and Hidalgo counties in central and southern Texas (Schmidly, 1991). The subspecies are *M. v. incautus* (J. A. Allen, 1896) in the south and *M. v. magnamolaris* Choate and Hall, 1967, northwestwardly. Yancey and Jones (1996*a*) reported first county records (for *M. v. incautus*) from Caldwell, Milam, and Nueces counties of southeastern Texas.

Myotis volans (long-legged myotis).— Known from central Trans-Pecos Texas and by enigmatic specimen from Knox County, far to the northeast. The subspecies is *M. v. interior* Miller, 1914.

Myotis yumanensis (Yuma myotis).— Recorded from southern Trans-Pecos region and from just east of Pecos River in Val Verde County; there is also a specimen in the Texas Natural History Collection from Starr County. The subspecies is *M. y. yumanensis* (H. Allen, 1864).

Lasionycteris noctivagans (silver-haired bat).— Occurs statewide as migrant in spring and autumn. *Lasionycteris noctivagans* Le Conte, 1831, is a monotypic species. Bats listed by Davis (1974) and Schmidly (1991) from Medina County actually are from Bandera County.

Pipistrellus hesperus (western pipistrelle).— Widely distributed in suitable rocky habitats in Trans-Pecos region; also occurs eastward to Knox, Haskell, and Uvalde counties and northward along eastern escarpment of Llano Estacado at least to Randall, Briscoe, and Floyd counties. The subspecies is *P. h. maximus* Hatfield, 1936. Dowler et al. (1992) reported specimens of western pipistrelle from Tom Green County, in east-central Texas.

Pipistrellus subflavus (eastern pipistrelle).— Known from much of eastern and central Texas, westward to breaks of Llano Estacado and Val Verde County, and south to Padre Island and Cameron County. The subspecies are *P. s. subflavus* (F. Cuvier, 1832) over much of the range of the species in the state and *P. s. clarus* Baker, 1954, in the extreme southwest. Dowler et al. (1992) reported specimens of eastern pipistrelles from Tom Green and Irion counties. Jones et al. (1993) reported the species from Lubbock County on the Llano Estacado. Yancey et al. (1995*b*) reported an extralimital eastern pipistrelle from Big Bend Ranch State Park in Presidio County.

Eptesicus fuscus (big brown bat).— Widely distributed over most of eastern and western parts of state; curiously, unrecorded from much of central and southern Texas. The subspecies are *E. f. fuscus* (Palisot de Beauvois, 1796) in the east and northwest, and *E. f. pallidus* Young, 1908, in the Trans-Pecos (Jones and Manning, 1990).

Lasiurus blossevillii (western red bat).— Only recently recognized as distinct from *L. borealis* (Baker at al., 1988); known in Texas only from the Sierra Vieja Mountains, Presidio County. The subspecies is *L. b. teliotis* (H. Allen, 1891).

Lasiurus borealis (eastern red bat).— Statewide in suitable wooded habitats, but uncommon westwardly; migratory, but some individuals probably over-winter in Texas. *Lasiurus borealis* (Müller, 1776) is a monotypic species (Baker et al., 1988). Yancey and Jones (1996*a*) report several new county records for this species within the known distribution.

Lasiurus cinereus (hoary bat).— Statewide as migrant in spring and autumn; additionally, it is possible that some females bear and raise young in Texas in late spring and summer. The subspecies is *L. c. cinereus* (Palisot de Beauvois, 1796).

Lasiurus ega (southern yellow bat).— Known in Texas only from Rio Grande Valley in Cameron County northward along Gulf Coast to Nueces County. The subspecies probably is *L. e. panamensis* (Thomas, 1901).

Lasiurus intermedius (northern yellow bat).— Occurs only in southeastern part of state. The subspecies are *L. i. intermedius* H. Allen, 1862, from Victoria County southward and *L. i. floridanus* (Miller, 1902) from Bexar and Travis counties eastward, north at least to Shelby County (Schmidly, 1991). Nedbal et al. (1994) reported this species from Galveston Island and suggest that a resident population might exist there.

Lasiurus seminolus (Seminole bat).— Known in state only from eastern part, west at least to Burleson County. *Lasiurus seminolus* (Rhoads, 1895) is a monotypic species. Yancey and Jones (1996*a*) list a county record for the northern part of the distribution (Harrison County) and a new county record from the western part of the known distribution (Fayette County).

Lasiurus xanthinus (western yellow bat).— Reported recently from the Big Bend region of Texas (Higginbotham et al., in press). *Lasiurus xanthinus* (Thomas, 1897) is a monotypic form.

Nycticeius humeralis (evening bat).— Occupies approximately eastern third of state, westward to a line drawn to include (north to south) Tarrant, San Saba, Bandera, Real, and Kinney counties (Schmidly, 1991). The subspecies is *N. h. humeralis* (Rafinesque, 1818). Dowler et at. (1992) reported the species from Tom Green County, the westernmost record in central Texas.

Euderma maculatum (spotted bat).— Recorded only from Big Bend National Park, but to be looked for elsewhere in Trans-Pecos region. *Euderma maculatum* (J. A. Allen, 1891) is a monotypic species.

Plecotus townsendii (Townsend's big-eared bat).— Cavernicolus species known from approximately western half of state, eastward at least to Foard and Kimble counties. The subspecies is *P. t. pallescens* (Miller, 1897). We follow Jones et al. (1997) in the use of *Plecotus* as the correct genus (however, see Frost and Timm (1992) and Tumlison and Douglas (1992) concerning the use of *Corynorhynus* as the generic name).

Plecotus rafinesquii (Rafinesque's big-eared bat).— Occurs only in extreme eastern Texas, the westernmost records being from Montgomery, Nacogdoches, and Polk counties. The subspecies is *P. r.*

macrotis Le Conte, 1831. We follow Jones et al (1997) in the use of *Plecotus* as the correct generic name. Theis (1994) reported this bat from Walker County, a locality west of its known or documented distribution. Yancey and Jones (1997), likewise, report on a specimen from Shelby County in extreme East Texas.

Antrozous pallidus (pallid bat).— Common resident in western half of state. The subspecies recorded from most of the range in Texas is *A. p. pallidus* (Le Conte, 1856), but *A. p. bunkeri* Hibbard, 1934, occurs in the vicinity of the Red River and in the Panhandle (Manning et al., 1988).

Family Molossidae
(free-tailed bats)

Tadarida brasiliensis (Brazilian free-tailed bat).— Statewide in warm months; most individuals of western and central populations migrate southward in winter, but populations in extreme eastern Texas frequently are resident year round. The currently recognized subspecies are *T. b. cynocephala* (Le Conte, 1831) in the eastern fourth of the state and *T. b. mexicana* (Saussure, 1860) elsewhere. However, the systematics of these two taxa currently are under study and they possibly represent distinct species.

Nyctinomops femorosaccus (pocketed free-tailed bat).— Recorded in state only from Big Bend area; to be looked for elsewhere in Trans-Pecos region. *Nyctinomops femorosaccus* (Merriam, 1884) is a monotypic species.

Nyctinomops macrotis (big free-tailed bat).— Known from western part of state only as seasonal migrant, except for breeding population in Big Bend National Park in warm months; migrants also recorded from Brazos, Matagorda, and San Patricio counties. *Nyctinomops macrotis* (Gray, 1839) is a monotypic species.

Eumops perotis (western mastiff bat).— Known as summer resident from Brewster, Presidio, and Val Verde counties; winter range unknown. The subspecies is *E. p. californicus* (Merriam, 1890).

ORDER PRIMATES— PRIMATES

Family Cercopithecidae
(Old World monkeys)

**Macaca fuscata* (Japanese macaque).— Old World monkeys are included here because, "There are reliable reports of free-ranging groups of Japanese macaques in South Texas" (Jones et al., 1997:2). Many records center around or probably originated from near Dilley, in Frio County.

ORDER XENARTHRA— EDENTATES

Family Dasypodidae
(armadillos)

Dasypus novemcinctus (nine-banded armadillo).— Occurs throughout much of state; absent only from most of Trans-Pecos and Panhandle. The subspecies is *D. n. mexicanus* Peters, 1864. See Jones et al. (1993) for records from the Llano Estacado. Roberts, Yancey, and Jones (1997) record a specimen from Hall County in the Texas Panhandle.

ORDER LAGOMORPHA— LAGOMORPHS

Family Leporidae
(hares and rabbits)

Sylvilagus aquaticus (swamp rabbit).— Found in eastern third of state, west to Palo Pinto, Eastland, Brown and Travis counties (Garner et al., 1990). *S. aquaticus* (Bachman, 1837) evidently is a monotypic species. Baccus and Wallace (1997) reviewed the distribution and habitat affinity of the swamp rabbit in Texas. They list several new localities of record (specimens and "sign") for the species along the northern (to Mills County), western (to Kerr County), and southern (to Bexar County) areas of the Edwards Plateau.

Sylvilagus audubonii (desert cottontail).— Occupies upland habitats in western half of Texas. The subspecies are *S. a. minor* (Mearns, 1896) in the southern Trans-Pecos eastward to Val Verde County, *S. a. neomexicanus* Nelson, 1907, in the northern part of the range in the state (south to Reeves and northern Brewster counties), and *S. a. parvulus* (J. A. Allen, 1904) from Llano County southward in south-central Texas to the Rio Grande.

Sylvilagus floridanus (eastern cottontail).— Occurs in eastern three fourths of state and parts of Trans-Pecos region. The subspecies are *S. f. alacer* (Bangs, 1896) in eastern Texas, *S. f. chapmani* (J. A. Allen, 1899) in the central and southern parts of the state, *S. f. llanensis* Blair, 1938, on the Llano Estacado, and *S. f. robustus* (Bailey, 1905) from the mountains of the Trans-Pecos. Some authorities (Davis, 1974; Ruedas, in press) have regarded *robustus* as specifically distinct from *floridanus*.

Lepus californicus (black-tailed jackrabbit).— Found throughout Texas except in extreme southeast. Four subspecies have been recorded from the state, but this species is badly in need of taxonomic review. The races are: *L. c. eremicus* J. A. Allen, 1894, in the El Paso area; *L. c. melanotis* Mearns, 1890, in the north; *L. c. merriami* Mearns, 1896, in the south and southeast; and *L. c. texianus* Waterhouse, 1848, on the western Edwards Plateau and in the eastern Trans-Pecos. The type localities of two of the four subspecies listed above are in Texas *L. c. merriami* (Fort Clark, Kinney County) and *L. c. texianus* (restricted to 10 mi. S. Alpine, Brewster County, by Hoffmeister, 1986). The type localities of the other two are in Arizona (*L. c. eremicus*) and Kansas (*L. c. melanotis*).

ORDER RODENTIA— RODENTS

Family Sciuridae
(squirrels and allies)

Tamias canipes (gray-footed chipmunk).— Known from Guadalupe Mountains and Sierra Diablo in Culberson County. The subspecies is *T .c. canipes* (Bailey, 1902). Except for one species, all New World chipmunks were, for many years, assigned to the genus *Eutamias*. Recent investigators have suggested that all should be grouped into the single genus *Tamias* (Jones et al., 1992), but there is disagreement on this point.

Ammospermophilus interpres (Texas antelope squirrel).— Recorded from western and southern parts of Trans-Pecos region, and eastward at least to Crane and Reagan counties. *Ammospermophilus interpres* (Merriam, 1890) is a monotypic species.

Spermophilus mexicanus (Mexican ground squirrel).— Occurs throughout much of southern and western Texas (west to Culberson, Jeff Davis, and Presidio counties in Trans-Pecos), north almost to Red River just east of Panhandle. The subspecies is *S. m. parvidens* Mearns, 1896. This species may hybridize occasionally with *S. tridecemlineatus* at places where their ranges meet or overlap.

Spermophilus spilosoma (spotted ground squirrel).— Known from approximately western half of Texas and also southward on Rio Grande Plain. The subspecies are *S. s. annectens* Merriam, 1893, in the southern part of the state, *S. s. canescens* Merriam, 1890, in the western Trans-Pecos, and *S. s. marginatus* Bailey, 1890, in the remainder of the range.

Spermophilus tridecemlineatus (thirteen-lined ground squirrel).— Recorded from northwestern part of state and in corridor in east-central Texas southward to Gulf Coast. The subspecies are *S. t. arenicola* (Howell, 1928) in the Panhandle and adjacent areas to the south and *S. t. texensis* Merriam, 1898, elsewhere within the distribution in the state.

Spermophilus variegatus (rock squirrel).— Known from Trans-Pecos and south-central part of state. The subspecies are *S. v. buckleyi* Slack, 1861, in south-central Texas and *S. v. grammurus* (Say, 1823) to the west.

Cynomys ludovicianus (black-tailed prairie dog).— Occurs or once occurred in western half of state north of Rio Grande Plain; easternmost records from Montague County in north and Bexar County in south; now extirpated over parts of former range. The subspecies are *C. l. arizonensis* Mearns, 1890, in the Trans-Pecos and *C. l. ludovicianus* (Ord, 1815) elsewhere.

Sciurus carolinensis (eastern gray squirrel).— Native distribution includes eastern third of state, westward at least to Lavaca, Lee, and McLennan counties; introduced in Lubbock and perhaps other counties west of natural range. The subspecies is *S. c. carolinensis* Gmelin, 1788.

Sciurus niger (eastern fox squirrel).— Occurs in suitable habitats in eastern two-thirds of Texas; introduced at some places outside native range. The subspecies are *S. n. limitis* Baird, 1855, in most of the western part of the range in the state, *S. n. ludovicianus* Custis, 1806, in the east, and *S. n. rufiventer* E. Geoffroy St.-Hilaire, 1803, which occurs in the Canadian River drainage and adjacent areas of northwestern and extreme north-central Texas.

Glaucomys volans (southern flying squirrel).— Known from wooded areas in eastern third of state. The subspecies is *G. v. texensis* Howell, 1915.

Family Geomyidae
(pocket gophers)

Thomomys bottae (Botta's pocket gopher).— Recorded from much of Trans-Pecos Texas, eastward across the Edwards Plateau (Hollander et al., 1987*b*) and immediately adjacent areas at least to Kimble County. Ten subspecies have been recognized in Texas, eight restricted to suitable habitats in the Trans-Pecos region: *T. b. baileyi* Merriam, 1901; *T. b. guadalupensis* Goldman, 1936; *T. b. lachuguilla* Bailey, 1902; *T. b. limpiae* Blair, 1939; *T. b. pervarius* Goldman, 1938; *T. b. scotophilus* Davis, 1940; *T. b. spatiosus* Goldman, 1938; and *T. b. texensis* Bailey, 1902. Additionally, *T. b. limitaris* Goldman, 1936, occurs in the eastern Trans-Pecos and eastward across the Pecos River onto the western part of the Edwards Plateau, and *T. b. confinalis* Goldman, 1936, occupies parts of the Edwards Plateau to the east.

Geomys arenarius (desert pocket gopher).— Known only from El Paso County. The subspecies is *G. a. arenarius* Merriam, 189S. Hafner and Geluso (1983) placed the two known subspecies of *G. arenarius* as races of the earlier-named *G. bursarius*. Accordingly, the status of *arenarius*, which is geographically isolated from other populations of *Geomys* in Texas, remains uncertain (see Qumsiyeh et al., 1988).

Geomys attwateri (Attwater's pocket gopher).— Recorded from south-central part of eastern Texas, from Milam County southward to Matagorda and San Patricio counties, and southwestward to Atascosa County. *Geomys attwateri* Merriam, 1895, is a monotypic species.

Geomys breviceps (Baird's pocket gopher).— Occurs in eastern fourth of state; reported from Delta County southward at least to Falls County, and hence on southward east of Brazos River to Gulf Coast. The subspecies in Texas is *G. b. sagittalis* Merriam, 1895.

Geomys bursarius (plains pocket gopher).— Reported from northwestern and north-central Texas, south to Coke and Midland counties, and eastward to McLennan and Montague counties. Two subspecies currently are thought to occur in the state—*G. b. jugossicularis* Hooper, 1940, in the extreme northwestern part of the Panhandle and *G. b. major* Davis, 1940, over the remainder of the distribution in Texas.

Geomys knoxjonesi (Jones' pocket gopher).— Known in Texas from southwestern part of Llano Estacado and adjacent areas immediately to the south; also known from adjoining southeastern New Mexico. Originally named as a subspecies of *G. bursarius*, *G. knoxjonesi* Baker and Genoways, 1975, is a monotypic species (Baker et al., 1989; Bradley et al., 1991).

Geomys personatus (Texas pocket gopher).— Known in southern part of state, frequently in isolated populations, from Val Verde, Kinney, Atascosa, and Karnes counties southward in east to Rio Grande. Seven subspecies presently are recognized (Williams and Genoways, 1981): *G. p. davisi* Williams and Genoways, 1981, in the Rio Grande Valley in western Webb and Zapata counties; *G. p. fallax* Merriam, 1895, from Nueces Bay northward to Karnes County; *G. p. fuscus* Davis, 1940, which is known only from Kinney and Val Verde counties; *G. p. maritimus* Davis, 1940, in Kleberg and Nueces counties; *G. p. megapotamus* Davis, 1940, from La Salle County southeastward to the south side of Baffin Bay and to the Rio Grande; *G. p. personatus* True, 1889, on Mustang and Padre islands; and *G. p. streckeri* Davis, 1940, which is restricted to Dimmit and eastern Zapata counties.

Geomys texensis (Llano pocket gopher).— Recorded only from Gillespie, Llano, and Mason counties on the northeastern part of the Edwards Plateau. Both *texensis* and a synonym, *llanensis*, formerly were regarded as subspecies of *G. bursarius* (see Block and Zimmerman, 1991). *Geomys texensis* Merriam, 1895, is monotypic.

Cratogeomys castanops (yellow-faced pocket gopher).— Found in western third of state from Panhandle southward to Val Verde County and throughout Trans-Pecos Texas; isolated populations recorded from Cameron and Maverick counties along the Rio Grande. Seven subspecies currently are thought to occur in the state (Hollander, 1990): *C. c. angusticeps* Nelson and Goldman, 1934, known only from the vicinity of Eagle Pass, Maverick County; *C. c. clarkii* (Baird, 1855) from the Big Bend and much of the southern Trans-Pecos area; *C. c. dalquesti* Hollander, 1990, which occurs in west-central Texas to the north of Edwards Plateau but southeast of the Llano Estacado; *C. c. lacrimalis* Nelson and Goldman, 1934, from the New Mexican border south in the Pecos drainage to Reeves, Ward, and Winkler counties; *C. c. parviceps* (Russell, 1968) in the far western Trans-Pecos; *C. c. perplanus* Nelson and Goldman, 1934, from the High Plains of northwestern Texas; and *C. c. tamaulipensis* Nelson and Goldman, 1934, known only from Cameron County.

Family Heteromyidae
(pocket mice and kangaroo rats)

Perognathus flavescens (plains pocket mouse).— Recorded in Texas from El Paso County and from High Plains and adjacent areas in northwestern part of state, east to Wilbarger County and south at least to Midland and Ward counties (Jones et al., 1991). The subspecies are *P. f. copei* Rhoads, 1894, in northwestern Texas and *P. f. melanotis* Osgood, 1900, in the western Trans-Pecos.

Perognathus flavus (silky pocket mouse).— Found in Texas Panhandle and the Trans-Pecos. The subspecies in Texas probably is *P. f. flavus* Baird, 1855. We acknowledge the need for continued systematic and biogeographic work on this species and its congener, *P. merriami*, in Texas and surrounding areas.

Perognathus merriami (Merriam's pocket mouse).— Found in western two-thirds of state. The subspecies in Texas probably are *P. m. gilvus* Osgood, 1900, in the western part of the Panhandle, Trans-Pecos, and western Edwards Plateau and *P. m. merriami* J. A. Allen 1892, in the eastern part of the Panhandle, eastern Edwards Plateau and South Texas. As mentioned in the previous account, the systematic relationship of this taxon and *P. flavus* is not fully resolved.

Chaetodipus hispidus (hispid pocket mouse).— Occurs throughout Texas save for extreme southeastern part. The subspecies are *C. h. hispidus* (Baird, 1858) in the east, *C. h. paradoxus* (Merriam, 1889) in the western one-third of the state, and *C. h. spilotis* in a limited area of north-central Texas (type locality at Gainesville, Cooke County). The systematics of this species is in need of serious review.

Chaetodipus intermedius (rock pocket mouse).— Reported only from western part of the Trans-Pecos. The subspecies is *C. i. intermedius* (Merriam, 1889).

Chaetodipus nelsoni (Nelson's pocket mouse).— Occurs in southern and central Trans-Pecos region, and just east of Pecos River in Upton and Val Verde counties (Hollander et al., 1987b). The subspecies is *C. n. canescens* (Merriam, 1904).

Chaetopidus eremicus (Chihuahuan desert pocket mouse).— Ranges throughout Trans-Pecos Texas, eastward at least to Crane and Val Verde counties (Jones and Manning, 1991). *C. eremicus* (Mearns, 1898) is a monotypic species. We follow Lee et al. (1996) in the use of this name combination.

Dipodomys compactus (Gulf Coast kangaroo rat).— Recorded from eastern two-thirds of South Texas mainland and from Mustang and Padre islands. The two recognized subspecies are *D. c. compactus* True, 1889, on the barrier islands and *D. c. sennetti* (J. A. Allen, 1891) on the mainland.

Dipodomys elator (Texas kangaroo rat).— Occurs in north-central Texas, from Cottle and Motley counties in west to Montague County in east. *Dipodomys elator* Merriam, 1894, is a monotypic species.

Dipodomys merriami (Merriam's kangaroo rat).— Ranges throughout Trans-Pecos region; known east of Pecos River from Crockett, Gaines, Ector, Martin, Midland, Reagan, and Winkler counties. The subspecies is *D. m. ambiguus* Merriam, 1890.

Dipodomys ordii (Ord's kangaroo rat).— Known from western and southern parts of state. The subspecies in Texas are: *D. o. medius* Setzer, 1949, from the central Llano Estacado southward east of the Pecos River to Crane, Crockett, and Upton counties, and east to Jones County; *D. o. obscurus* (J. A. Allen, 1903) in the western, central, and southern parts of the Rio Grande Plain and in the southern Big Bend area; *D. o. ordii* Woodhouse, 1853, in most of the Trans-Pecos region; and *D. o. richardsoni* (J. A. Allen, 1891) from the Panhandle and adjacent areas southward at least to Floyd County and east to Montague County.

Dipodomys spectabilis (banner-tailed kangaroo rat).— Occurs in western and central Trans-Pecos region; reported east of Pecos River from Andrews, Dawson, Ector, Gaines, Martin, Ward, and Winkler counties. The subspecies is *D. s. baileyi* Goldman, 1923.

Liomys irroratus (Mexican spiny pocket mouse).— Known only from extreme southern Texas (Cameron, Hidalgo, and Willacy counties). The subspecies is *L. i. texensis* Merriam, 1902.

Family Castoridae
(beavers)

Castor canadensis (American beaver).— Found over most of state where suitable aquatic habitat prevails; absent from Llano Estacado and some adjacent areas and from much of Trans-Pecos region. The subspecies are *C. c. mexicanus* Bailey, 1913, along the Rio Grande and its immediate tributaries and *C. c. texensis* Bailey, 1905, to the north. Thorton and Lee (1996) report a specimen from Taylor County, in central Texas.

Family Muridae
(mice and rats)

Oryzomys couesi (Coues' rice rat).— Known in state only from Cameron and Hidalgo counties; probably occurs also in immediately adjacent areas. The subspecies is *O. c. aquaticus* J. A. Allen, 1891.

Oryzomys palustris (marsh rice rat).— Distributed in eastern part of Texas, west to Hunt and Lee counties and hence southward at least to Willacy County. The subspecies is *O. p. texensis* J. A. Allen, 1894. Stangl and McDonough (1997:260) report a specimen from Fannin County which they say "represent a northwestern marginal record of the marsh rice rat in the state."

Reithrodontomys fulvescens (fulvous harvest mouse).— Occurs in eastern and central Texas (west to Armstrong, Childress, and Wheeler counties in north) and in parts of Trans-Pecos region. The subspecies are *R. f. aurantius* J. A. Allen, 1895, in the eastern part of the state, *R. f. canus* Benson, 1939, in the eastern and southern Trans-Pecos, *R. f. intermedius* J. A. Allen, 1895, on the Rio Grande Plain and in adjacent areas of southern Texas, and *R. f. laceyi* J. A. Allen, 1896, in the central part of the state.

Reithrodontomys humulis (eastern harvest mouse).— Known from eastern part of state, west to Fort Bend, Hunt, and McLennan counties. The subspecies is *R. h. merriami* J. A. Allen, 1895.

Reithrodontomys megalotis (western harvest mouse).— Occurs in western Texas, from Panhandle southward to Trans-Pecos region. The subspecies are *R. m. aztecus* J. A. Allen, 1893, in the northern part of the range and *R. m. megalotis* (Baird, 1858) to the south.

Reithrodontomys montanus (plains harvest mouse).— Found in western and central parts of state, east and southeast at least to Madison and Bexar counties, respectively. The subspecies are *R. m. griseus* Bailey, 1905, throughout most of the range in Texas and *R. m. montanus* (Baird, 1855) in the Trans-Pecos region. Jones, et al. (1993) reported the species from near Big Bend National Park, in Brewster County. Goetze et al. (1993) listed several records from the Edwards Plateau.

Peromyscus attwateri (Texas mouse).— Known only from central part of state, south to Crockett, Edwards, and Travis counties, and west to eastern edge of Llano Estacado. *Peromyscus attwateri* (J. A. Allen, 1893) is a monotypic species.

Peromyscus boylii (brush mouse).— Occurs in Texas only in Trans-Pecos region and not along scarp of

Llano Estacado as once claimed (Choate, 1997). The subspecies is *P. b. rowleyi* (J. A. Allen, 1893).

Peromyscus nasutus (northern rock mouse).— Known only from mountainous parts of western and southern Trans-Pecos Texas. We employ the specific name *nasutus* (instead of *difficilis*) for this mouse following Carleton (1989). The subspecies are *P. n. nasutus* (J. A. Allen, 1891) from the Guadalupe Mountains in Culberson County and *P. n. penicillatus* Mearns, 1896, from Brewster, El Paso, and Presidio counties. The subspecies *nasutus* also has been taken along the breaks of the Llano Estacado in eastern New Mexico, but a few miles west of the Texas border (Choate et al., 1991).

Peromyscus eremicus (cactus mouse).— Recorded from Trans-Pecos region southeastward along Rio Grande to Webb County. The subspecies is *P. e. eremicus* (Baird, 1858).

Peromyscus gossypinus (cotton mouse).— Found in woodlands in eastern fourth of state, west at least (north to south) to Hunt, Kaufman, Freestone, Leon, and Grimes counties. The subspecies is *P. g. megacephalus* (Rhoads, 1894). Stangl and McDonough (1997:260) report on specimens from Fannin County that "represent a marginal record from along the western boundary of the species in Texas."

Peromyscus leucopus (white-footed mouse).— State-wide in distribution. The subspecies, which are in need of systematic review, are *P. l. leucopus* (Rafinesque, 1818) in the eastern third of the state, *P. l. texanus* (Woodhouse, 1853) in central Texas (west to Brewster, Terrell, and Val Verde counties), and *P. l. tornillo* Mearns, 1896, in the Panhandle and much of the Trans-Pecos.

Peromyscus maniculatus (deer mouse).— Known from all but eastern part of state. The subspecies are as follows: *P. m. blandus* Osgood, 1904, in the Trans-Pecos and areas immediately to the east; *P. m. luteus* Osgood, 1905, in the Panhandle, probably south to Winkler County; *P. m. ozarkiarum* Black, 1935, which occurs sympatrically with the following race in Cooke, Denton, and Grayson counties; and *P. m. pallescens* J. A. Allen, 1896, in the eastern part of the range in Texas.

Peromyscus pectoralis (white-ankled mouse).— Recorded from most of Trans-Pecos region (west to Culberson and Hudspeth counties) and northeastward through central part of state to Oklahoma (eastern limits of range along Balcones Escarpment from Bexar County northward to McLennan County). The subspecies in Texas is *P. p. laceianus* Bailey, 1906.

Peromyscus truei (piñon mouse).— Recorded in state only from breaks of Llano Estacado and from Guadalupe Mountains. The subspecies are *P. t. comanche* Blair, 1943, from the breaks of the Llano in Armstrong, Briscoe, and Randall counties, and *P. t. truei* (Schufeldt, 1885) from the Guadalupes and the Llano breaks in Deaf Smith County just to the east of the New Mexican border (Choate et al., 1991). The distribution and status of the endemic Palo Duro mouse recently was reviewed by Yancey et al. (1996*a*).

Ochrotomys nuttalli (golden mouse).— Occurs in woodlands of extreme eastern Texas, west at least to Anderson and Houston counties. The subspecies is *O. n. lisae* Packard, 1969.

Baiomys taylori (northern pygmy mouse).— Distributed over eastern half to two-thirds of state, depending on latitude, except in extreme northeastern part, west at least to (north to south) Carson, Armstrong, Swisher, Lubbock, and Yoakum counties (see Choate et al., 1990, 1991); has expanded range substantially northward and westward in past few decades. The subspecies are *B. t. taylori* (Thomas, 1897) over most of the range in Texas and *B. t. subater* (Bailey, 1905) in the southeast.

Onychomys arenicola (Mearns' grasshopper mouse).— Ranges throughout all but southeastern part of Trans-Pecos Texas; recorded east of Pecos River from Crockett, Ward, and Winkler counties. The subspecies is *O. a. arenicola* Mearns, 1896. This mouse was regarded for many years as representing the species *O. torridus*.

Onychomys leucogaster (northern grasshopper mouse).— Known from western Trans-Pecos region and throughout central Texas south to Gulf Coast and Rio Grande. The subspecies are *O. l. albescens* Merriam, 1904, in El Paso and Hudspeth counties, *O. l. arcticeps* Rhoads, 1898, in the Panhandle and adjacent areas to the east, south to Crockett and Pecos counties, and *O. l. longipes* Merriam, 1899, from Tom Green and Terrell counties southward to the Rio Grande and southeastward to Nueces County. Thornton and Lee (1996) reported a Taylor County record for the Rolling Plains of north-central Texas.

Sigmodon fulviventer (tawny-bellied cotton rat).— Known from but a single locality in Davis Mountains of Jeff Davis County (Stangl, 1992). The subspecies is *S. f. dalquesti* Stangl, 1992.

Sigmodon hispidus (hispid cotton rat).— This murid is known to occur statewide. The subspecies are *S. h. berlandieri* Baird, 1855, from the Panhandle southward to the Trans-Pecos and the Rio Grande Plain and *S. h. texianus* (Audubon and Bachman, 1853) in the eastern and central parts of the state. Southwestern races of this species are in need of critical systematic review.

Sigmodon ochrognathus (yellow-nosed cotton rat).— Reported only from higher elevations in southern Trans-Pecos region. *S. ochrognathus* Bailey, 1902, is a monotypic species. Yancey and Jones (1996: 249) report a specimen taken from "a non-montane" habitat, in Presidio County. This cotton rat recently was taken at Elephant Mountain Wildlife Managment Area in Brewster County, Texas, in desert habitat (Heaney et al., in press).

Neotoma albigula (white-throated woodrat).— Found in Panhandle and broken country south of Red River, southeastward to Kerr and Llano counties, thence westward throughout much of southwestern part of state. The subspecies thought to occur in Texas are *N. a. albigula* Hartley, 1894, which occurs over most of the range in the state, *N. a. robusta* Blair, 1939, from the mountains of the southern Trans-Pecos, and *N. a. warreni* Merriam, 1908, from north of the Canadian River in the northern Panhandle. Rogers and Schmidly (1981) included *robusta* as a form of *N.a.albigula*.

Neotoma floridana (eastern woodrat).— Recorded from eastern part of Texas, south to Victoria County and westward to Edwards and Kerr counties. The subspecies are *N. f. attwateri* Mearns, 1897, which occupies the northern and western parts of the range in the state, and *N. f. rubida* Bangs, 1898, in the southeast. Additionally, *N. f. illinoensis* Howell, 1910, may be found in extreme northeastern Texas.

Neotoma mexicana (Mexican woodrat).— Known in Texas only from mountainous areas in Brewster, Culberson, Jeff Davis, and Presidio counties of Trans-Pecos region. The subspecies is *N. m. mexicana* Baird, 1855.

Neotoma micropus (southern plains woodrat).— Found in western two thirds of Texas, eastward to Johnson County in north and Gulf Coast in south. The subspecies are *N. m. canescens* J. A. Allen, 1891, in the western part of the range in the state and *N. m. micropus* Baird, 1855, in the east. Populations of this woodrat are in need of taxonomic review.

**Rattus norvegicus* (Norway rat).— Widespread in Texas in and near human habitations, but not so common as *R. rattus* in urban settings.

**Rattus rattus* (roof rat).— Common in urban environs throughout much of Texas, and sometimes found in or around human habitations in rural areas.

**Mus musculus* (house mouse).— State-wide in distribution, usually in close association with humans, but feral populations also are known. Some authors have argued recently that *Mus domesticus*, rather than *M. musculus*, was the house mouse introduced into North America, but most regard the former as no more than a subspecies of the latter (Bonhomme, 1986).

Microtus mexicanus (Mexican vole).— Recorded only from higher elevations in Guadalupe Mountains of Culberson County. The subspecies is *M. m. guadalupensis* Bailey, 1902.

Microtus ochrogaster (prairie vole).— Known only from single individual taken in Hardin County, in the southeast, in 1902, and by eight specimens recently reported from two counties (Hansford and Lipscomb) in northern Panhandle (Jones et al., 1988*b*; Choate and Killebrew, 1991), far to the northwest. According to Schmidly (1983), "this species is probably now extinct in eastern Texas." The subspecies there was *M. o. ludovicianus* Bailey, 1902. The subspecies in northwestern Texas probably is *M. o. taylori* Hibbard and Rinker, 1943.

Microtus pinetorum (woodland vole).— Found in eastern and central parts of state west to Montague County and south at least to Kerr and Newton counties. The subspecies are *M. p. auricularis* Bailey, 1898, in the southern part of the range in Texas and *M. p. nemoralis* Bailey, 1898, to the north.

Ondatra zibethicus (common muskrat).— Occurs only in suitable aquatic habitats in northern, southeastern, and southwestern parts of state. The subspecies are *O. z. cinnamominus* (Hollister, 1910) in the north (Canadian River drainage southeastward to Falls and Trinity counties), *O. z. ripensis* (Bailey, 1902) along the Rio Grande and its immediate tributaries in the Trans-Pecos region, and *O. z. rivalicius* (Bangs, 1895) on the Gulf Coastal Plain as far west as Brazoria County.

Family Erethizontidae
(New World porcupines)

Erethizon dorsatum (porcupine).— Known from western half of state, east at least to Clay and Kerr counties. According to Stangl et al. (1991), the one subspecies in Texas is *E. d. epixanthum* Brandt, 1835.

Family Myocastoridae
(myocastorids)

**Myocastor coypus* (nutria).— Found in aquatic habitats in eastern two-thirds of state, west at least to Pecos River. Hollander et al. (1992) report specimens from Terrell and Val Verde counties of the Trans-Pecos.

ORDER CARNIVORA— CARNIVORES

Family Canidae
(canids)

**Canis familiaris* (feral dog).— Feral animals common in many parts of Texas, especially eastwardly.

Canis latrans (coyote).— Known from variety of habitats throughout state; has moved into parts of eastern Texas since elimination of red wolves from much of that region. The subspecies are *C. l. latrans* Say, 1823, in the Panhandle, *C. l. texensis* Bailey, 1905, in the western half of the state south of the Panhandle, and *C. l. frustror* Woodhouse, 1851, in the eastern half of Texas.

Canis lupus (gray wolf).— Once ranged throughout western part of state at least as far east as McLennan County; no resident gray wolves remain in Texas, but individuals occasionally may cross into Trans-Pecos region from Mexico. The subspecies were *C. 1. nubilus* Say, 1823, in the Panhandle and eastward to Montague County, *C. l. monstrabilis* Goldman, 1937, throughout west-central and southern Texas, and *C. 1. baileyi* Nelson and Goldman, 1929, in extreme western Texas west of the Big Bend.

Canis rufus (red wolf).— Original range included most of area east of Balcones Fault Zone and west to Wichita County; endangered species that still may exist in Liberty, Chambers, and Jefferson counties. Subspecies included *C. r. gregoryi* Goldman, 1937, along the eastern border of the state and *C. r. rufus* Audubon and Bachman, 1851, in the remainder of the original range.

Vulpes velox (swift fox).— Known from grassland habitats of the Llano Estacado and the Panhandle (Davis and Schmidly, 1994; Choate, 1997). The subspecies in Texas is *V. v. velox* (Say, 1823). See comments in Jones et al. (1997) about specific status.

Vulpes macrotis (kit fox).— Known from arid and semi-arid regions of the Trans-Pecos and southwestern part of Edwards Plateau (Davis and Schmidly, 1994; Goetze, 1995). Subspecies in Texas is *V. m. neomexicana* Merriam, 1902. See comments in Jones et al. (1997) about specific status.

Vulpes vulpes (red fox).— Introduced in eastern and central Texas from elsewhere in North America beginning in about 1891, possibly to replace previously decimated populations; in any event, species recorded from late Pleistocene cave deposits and now ranges across central Texas from eastern part of state to lower Pecos River and probably to New Mexico state line. The subspecies is *V. v. fulva* (Desmarest, 1820).

Urocyon cinereoargenteus (common gray fox).— Occurs throughout state except possibly in northeastern part of Panhandle; especially common in eastern Texas. The subspecies are *U. c. floridanus* Rhoads, 1895, east of the Balcones Fault Zone and *U. c. scottii* Mearns, 1891, in the western two-thirds of the state.

Family Ursidae
(bears)

Ursus americanus (black bear).— Once ranged across state, except in the southernmost counties; in recent years, sighted only infrequently in extreme western Texas and in wooded regions of the east—probably animals that wandered into state, although small population of four to seven animals now present in Chisos Mountains, Big Bend National Park. The subspecies included *U. a. amblyceps* Baird, 1859, in the Trans-Pecos area and northward along the New Mexican border, *U. a. americanus* Pallas, 1780, in the central part of the state, and *U. a. luteolus* Griffith, 1821, in the east adjacent to Louisiana.

Ursus arctos (grizzly or brown bear).— Known by single specimen obtained in Davis Mountains in 1890; now extirpated in state. The subspecies was *U. a. horribilis* Ord, 1815.

Family Procyonidae
(procyonids)

Bassariscus astutus (ringtail).— Recorded from throughout state except in extreme lower Rio Grande and Coastal plains of southern Texas; usually associated with rocky and wooded habitats. The subspecies is *B. a. flavus* Rhoads, 1894. Gehrt (1993) reported the species from San Patricio County, and Anderson and Holzem (1992) document the species occurrence in Refugio County, both from the southeastern part of the state.

Procyon lotor (common raccoon).— Ubiquitous throughout state, especially in mesic areas and near human habitations. The subspecies are *P. l. hirtus* Nelson and Goldman, 1930, in the Panhandle north of the Canadian River, *P. l. mexicanus* Baird, 1858, in the western part of the Trans-Pecos, and *P. l. fuscipes* Mearns, 1914, throughout the remainder of the state.

Nasua narica (white-nosed coati).— Limited to southwestern and extreme southern parts of state. We follow Decker (1991) in treating the white-nosed coati as specifically distinct from *N. nasua* of South America. The subspecies in Texas is *N. n. molaris* Merriam, 1902.

Family Mustelidae
(mustelids)

Mustela frenata (long-tailed weasel).— Probably occurs state-wide, but scarce in most areas, especially in western and northern Texas. The subspecies include: *M. f. neomexicana* (Barber and Cockerell, 1898) mostly west of the 100th meridian; *M. f. texensis* Hall, 1936, in the central part of the state; *M. f. primulina* Jackson, 1913, in the extreme northeastern part of Texas; *M. f. arthuri* Hall, 1927, east of the Balcones Fault Zone in east-central and southeastern areas; and *M. f. frenata* Lichtenstein, 1831, in the southern part of the state along the Gulf Coast and adjacent to Mexico.

Mustela nigripes (black-footed ferret).— Ranged in northern and western parts of state as far as Cooke County in east and Pecos County in south. *Mustela nigripes* (Audubon and Bachman, 1851), which is a monotypic species, has been extirpated from Texas and from most other parts of its former geographic range.

Mustela vison (mink).— Known from approximately eastern half of state, westward to northern Panhandle, in habitats near permanent water. The subspecies is *M. v. mink* Peale and Palisot de Beauvois, 1796.

Taxidea taxus (American badger).— Found across state except in extreme eastern part; there is some evidence this species is extending its geographic range eastward in connection with changing land-use practices (Schmidly, 1983, 1984). The subspecies is *T. t. berlandieri* Baird, 1858.

Lontra canadensis (northern river otter).— Presently known only from about eastern fouth of state in major watersheds; probably extirpated from the Panhandle, north-central, and southern Texas (Schmidly, 1984). The subspecies is *L. c. lataxina* (F. Cuvier, 1823). See Jones et al. (1997:4) concerning the use of *Lontra* as the correct genus.

Family Mephitidae
(mephitids)

Spilogale gracilis (western spotted skunk).— Recorded from southwestern part of state, north as far as Garza and Howard counties and eastward to Duval County. The subspecies is *S. g. leucoparia* Merriam, 1890.

Spilogale putorius (eastern spotted skunk).— Occurs in Panhandle and north-central Texas as far south as Garza County, and in eastern part of state east of Balcones Escarpment. The subspecies is *S. p. interrupta* (Rafinesque, 1820). Although this species is widespread in Central America and Mexico, there is some chromosomal evidence that the population in Texas may be unique (Owen et al., 1996).

Mephitis macroura (hooded skunk).— Known only from Big Bend area and adjacent parts of central Trans-Pecos, northward to Reeves and Ward counties. *Mephitis. m. milleri* Mearns, 1897, is the recognized subspecies.

Mephitis mephitis (striped skunk).— Common throughout much of state, although somewhat less numerous in northern part of Trans-Pecos region than elsewhere; especially abundant in agricultural areas and near human habitations. *Mephitis. m. varians* Gray, 1837, occurs in the western part of Texas, whereas *M. m. mesomelas* Lichtenstein, 1832, is found east of the 100th meridian.

Conepatus leuconotus (eastern hog-nosed skunk).— Recorded from southern part of state from Aransas, San Patricio, and Webb counties southward. The subspecies is *C. l. texensis* Merriam, 1902.

Conepatus mesoleucus (common hog-nosed skunk).— Ranges across southwestern, central, and southern Texas (perhaps extirpated in Big Thicket—Schmidly, 1983), north at least to Collin and Lubbock counties. The subspecies are *C. m. mearnsi* Merriam, 1902, throughout most of the range in the state (east to Harris County) and *C. m. telmalestes* Bailey, 1905, from the Big Thicket area.

Family Felidae
(cats)

**Felis catus* (feral cat).— Feral animals fairly common in eastern Texas and probably in some other areas.

Leopardus pardalis (ocelot).— Recorded from Donley and McLennan counties in north, Brewster County in west, and Jefferson County in east; probably limited at present to favored habitats in three or four counties of southern Rio Grande Plain. The subspecies is *L. p. albescens* (Pucheran, 1855). See Jones et al. (1997) concerning the use of this name combination.

Leopardus wiedii (margay).— Known only from specimen taken in Maverick County in 1850s; probably now extinct in state. The subspecies was *L. w. cooperi* (Goldman, 1943). See Jones et al. (1997) concerning the use of this name combination.

Herpailurus yagouaroundi (jaguarundi).— Recorded in Texas only from Cameron, Hidalgo, Starr, and Willacy counties; current status unknown, but still may exist in three southernmost counties of state. *Herpailurus. y. cacomitli* (Berlandier, 1859), is the recognized subspecies. See Jones et al. (1997) concerning the use of this name combination.

Puma concolor (mountain lion).— Once ranged throughout state; now known certainly, except for occasional occurrences northward, only in desert mountain ranges of Trans-Pecos region, especially in Big Bend National Park, on parts of Edwards Plateau, and in dense brushlands of Rio Grande Plain. The subspecies is *P. c. stanleyana* (Goldman, 1938). We follow Hemmer (1978) and Kratochvil (1982) in the use of *Puma* as the correct genus.

Panthera onca (jaguar).— Once ranged northward into central Texas as far as Mills County and along Gulf Coast. The subspecies was *P. o. veraecrucis* (Nelson and Goldman, 1933).

Lynx rufus (bobcat).— Occurs in variety of habitats throughout state. According to Schmidly and Read (1986), only one subspecies, *L. r. texensis* J. A. Allen, 1895, is found in Texas.

ORDER ARTIODACTYLA— EVEN-TOED UNGUALTES

Family Suidae
(pigs)

**Sus scrofa* (feral pig).— Sizeable populations of pigs, derived from domestic animals that became feral and from animals introduced for hunting, occur in various places on Rio Grande and Coastal plains and in wooded country of eastern Texas.

Family Tayassuidae
(peccaries)

Pecari tajacu (collared peccary).— Once distributed over much of state; now restricted to southwestern and south-central Texas, and brush country south of San Antonio; an introduced population has survived about 40 years along Red River in Wilbarger County. The subspecies is *P. t. angulatus* (Cope, 1889). We follow Miller and Kellogg (1955) in the use of *Pecari* as the correct genus. Also, see Jones et al. (1997) concerning the use of this name combination.

Family Cervidae
(cervids)

**Cervus axis* (axis deer).— Native of India; introduced into Texas in approximately 1932, and now occurs in a number of counties in central and southern parts of state. More than 15,000 individuals are thought to be free-living (Traweek, 1985).

**Cervus dama* (fallow deer).— Native of western Palaearctic Region, east to Iran and south to North Africa. According to the most recent survey of exotic ungulates (Traweek, 1985), more than 10,000 now occur in Texas, about one-third outside confinement, mostly on the eastern Edwards Plateau and in adjacent areas.

Cervus elaphus (wapiti or elk).— Native to Guadalupe Mountains prior to extirpation by 1900; reintroduced into Guadalupes in 1928, and more recently in the Davis Mountains, and viable population still extant there. The native subspecies was *C. e. merriami* Nelson, 1902; the reintroduced animals are *C. e. nelsoni* Bailey, 1935.

**Cervus nippon* (sika deer).— Native of Orient that occurs in Texas primarily in central part of state; about 2500 free-ranging animals of a total of some 5560 individuals in the mid-1980s.

Odocoileus hemionus (mule deer).— Occurs over most of Trans-Pecos and Panhandle regions of Texas and in some areas immediately east thereof, partly as a result of reintroductions. The subspecies is *O. h. crooki* (Mearns, 1897).

Odocoileus virginianus (white-tailed deer).— Distributed in suitable wooded and brushy habitats throughout state. Originally, the subspecies included *O. v. carminis* (Goldman and Kellogg, 1940) known only from the Big Bend area, *O. v. macroura* (Rafinesque, 1817) in the extreme northeastern corner of the state, *O. v. mcilhennyi* (F. W. Miller, 1928) along the Gulf Coast, and *O. v. texana* (Mearns, 1898) throughout the central part of Texas. Native animals of the subspecies *O. v. mcilhennyi* and *O. v. macroura* were eliminated in eastern Texas; the area was restocked with individuals of *O. v. texana* (see Schmidly, 1983). Hybridization between white-tailed and mule deer has been reported from the eastern Trans-Pecos, and probably occurs also in adjacent areas.

Family Antilocapridae
(pronghorn)

Antilocapra americana (pronghorn).— Formerly known in western twothirds of Texas as far east as McLennan and Robertson counties; currently found only in scattered herds in north-central and western parts ofstate, especially in Trans-Pecos region and western part of Edwards Plateau. The subspecies are *A. a. americana* (Ord, 1815) in the Panhandle and *A. a. mexicana* Merriam, 1901, in western and central Texas, although reintroductions, beginning in the late 1930s, to augment a declining population may have altered this situation.

Family Bovidae
(bovids)

**Boselaphus tragocamelus* (nilgai).— Native of India and Pakistan; more than 15,000 now free-living in south-central and southern Texas.

Bos bison (bison).— Before extirpation, ranged throughout state except in dense woods of Big Thicket area; now present in Texas only in private herds on some ranches. The subspecies is *B. b. bison* (Linnaeus, 1758).

Ovis canadensis (mountain sheep).— Extirpated from desert mountain ranges in Trans-Pecos Texas; reintroduced, however, into this area where there now is an extant population. The native subspecies was *O. c. mexicana* Merriam, 1901, but some introductions of other subspecies have been made.

**Ammotragus lervia* (Barbary sheep or aoudad).— Native of North Africa; first introduced into Panhandle of Texas in 1957. Herds now exist on caprock along much of eastern edge of Llano Estacado, in rough country of Trans-Pecos, and on parts of Edwards Plateau. The total population in the wild exceeds 5000 (Traweek, 1985).

**Antilope cervicapra* (blackbuck).— Native to India and Pakistan; approximately 20,000 individuals now occur in Texas, but relatively few are found outside controlled areas.

LITERATURE CITED

Anderson, J. T., and A. M. Holzem. 1992. First record of a ringtail (*Bassariscus astutus*) from Refugio County. Texas J. Sci., 44:258.

Baccus, J. T. , and M. W. Wallace. 1997. Distribution and habitat affinity of the swamp rabbit (*Sylvilagus aqauticus*: Lagomorpha: Leporidae) on the Edwards Plateau of Texas. Occas. Papers Mus., Texas Tech Univ., 167:1-13.

Baker, R. J., J. C. Patton, H. H. Genoways, and J. W. Bickham. 1988. Genic studies of Lasiurus (Chiroptera: Vespertilionidae). Occas. Papers Mus., Texas Tech Univ., 117: 1-15.

Baker, R. J., S. K. Davis, R. D. Bradley, M. J. Hamilton, and R. A. Van Den Bussche. 1989. Ribosomal-DNA, mitochondrial-DNA, chromosomal, and allozymic studies on a contract zone in the pocket gopher, *Geomys*. Evolution, 43:63-75.

Block, S. G., and E. G. Zimmerman. 1991. Allozymic variation and systematics of plains pocket gophers (*Geomys*) in south-central Texas. Southwestern Nat., 36:29-36.

Bonhomme, F. 1986. Evolutionary relationships in the genus *Mus*. Current Topics Microbiol. Immunol., 127:19-34.

Bradley, R. D., S. K. Davis, and R. J. Baker. 1991. Genetic control of premating-isolating behavior: Kaneshiro's hypothesis and asymmetrical sexual selection in pocket gophers. J. Heredity, 82:192-196.

Carleton, M. D. 1989. Systematics and evolution. Pp. 7-141, *in* Advances in the study of *Peromyscus* (Rodentia) (G. L. Kirkland, Jr., and J. N. Layne, eds.), Texas Tech Univ. Press, Lubbock, (iv) + 367 pp.

Choate, L. L. 1990. First record of the mole, *Scalopus aquaticus*, on the Llano Estacado of western Texas. Texas J. Sci., 42:207.

Choate, L. L., and F. C. Killebrew. 1991. Distributional records of the California myotis and the prarie vole in the Texas Panhandle. Texas J. Sci., 43:214-215.

Choate, L. L., J. K. Jones, Jr., R. W. Manning, and C. Jones. 1990. Westward ho: continued dispersal of the pygmy mouse, *Baiomys taylori*, on the Llano Estacado and in adjacent areas of Texas. Occas. Papers Mus., Texas Tech Univ., 134: 1-8.

Choate, L. L., R. W. Manning, J. K. Jones, Jr., C. Jones, and T. R. Mollhagen. 1991. Records of mammals from the Llano Estacado and adjacent areas of Texas and New Mexico. Occas. Papers Mus., Texas Tech Univ., 138:1-11.

Choate, L.L. 1997. Distribution and natural history of mammals on the Llano Estacado of western Texas and eastern New Mexico. Spec. Publ. Mus., Texas Tech Univ., 40:1-240.

Choate, L.L., R. W. Manning, J. K. Jones, Jr., C. Jones, and S.E. Henke. 1992. Mammals from the southern border of the Kansan Biotic Province in western Texas. Occas. Papers Mus., Texas Tech Univ., 152:1-34.

Davis, W. B. 1974. The mammals of Texas. Bull. Texas Parks Wildlife Dept., 41:1-294.

Davis, W. B., and D. J. Schmidly. 1994. The mammals of Texas. Texas Parks and Wildlife Department, Austin, x + 338 pp.

Decker, D. M. 1991. Systematics of the coatis, genus *Nasua* (Mammalia: Procyonidae). Proc. Biol. Soc. Washington, 104:370-386.

Dowler, R. C., T. C. Maxwell, and D. S. Marsh. 1992. Noteworthy records of bats from Texas. Texas J. Sci., 44:121-123.

Dowler, R. C. , and R. A. Boyd. 1996. A range extension for the least shrew (*Cryptotis parva*) in west-central Texas. Texas J. Sci.,48:168-170.

Dragoo, J. W., J. R. Choate, T. L. Yates, and T. P. O'Farrell. 1990. Evolutionary and taxonomic relationships among North American arid-land foxes. J. Mamm., 71:318-332.

Frost, D. R., and R. M. Timm. 1992. Phylogeny of plecotine bats (Chiroptera: "Vespertilionidae"): summary of the evidence and proposal of a logically consistent taxonomy. Amer. Mus. Novit., 3034:1-16.

Garner, H. W., T. G. Joy, K. D. Huckabee, and R. M. Pitts. 1990. Additional distributionalrecords of mammals along the boundary of the Kansan-Texan biotic provinces in northcentral Texas. Texas J. Sci., 42:308-310.

Gehrt, S. D. 1993. A ringtail (*Bassariscus astutus*) recorded from San Patricio County, Texas. Texas J. Sci., 45: 359.

Goetze, J. R., F. D. Yancey, II, and A. M. Wallace. 1993. Additional records of the plains pocket mouse (*Reithrodontomys montanus*) from the Edwards Plateau, Texas. Texas J. Sci., 45:358-359.

Goetze, J. R. 1998. The mammals of the Edwards Plateau, Texas. Spec. Publ. Mus., Texas Tech Univ.,41:1-263.

Goetze, J. R., R. W. Manning, F. D. Yancey, II, and C. Jones. 1996. The mammals of Kimble County, Texas. Occas. Papers Mus., Texas Tech Univ., 160:1-31.

Hafner, J. C., and K. N. Geluso. 1983. Systematic relationships and historical zoogeography of the desert pocket gopher, *Geomys arenarius*. J. Mamm., 64:405-413.

Hall. E. R. 1981. The mammals of North America. John Wiley & Sons, New York, second edition, 2: vi+601-1181+*90*.

Heaney, M. R., E. J. Cook, and R. W. Manning. In press. Noteworthy record of the yellow-nosed cotton rat (*Sigmodon ochrognathus*) from Trans-Pecos Texas.

Hemmer, H. 1978. The evolutionary systematics of the living Felidae: present status and the current problems. Carnivore, 1:71-79.

Higginbotham, J.L., L.K. Ammerman, and M.T. Dixon. In press. First record of *Lasiurus xanthinus* (Chiroptera: Vespertilionidae) in Texas. Southwestern Nat.

Hoffmeister, D. F. 1986. Mammals of Arizona. Univ. Arizona Press, Tucson, xx + 602 pp.

Hollander, R. R. 1990. Biosystematics of the yellow-faced pocket gopher, *Cratogeomys castanops* (Rodentia: Geomyidae) in the United States. Spec. Publ. Mus., Texas Tech Univ., 33:1-62.

Hollander, R. R, and K. M. Hogan. 1992. Occurrence of the opossum, *Didelphis virginiana*, in the Trans-Pecos of Texas. Texas J. Sci., 44:127-128.

Hollander, R. R., R. R. Robertson, and R. J. Kinucan. 1992. First records of the nutria, *Myocastor coypu*, in the Trans-Pecos region of Texas. Texas. J. Sci., 44:117.

Jones, C., R. S. Hoffmann, D. D. Rice, M. D. Engstrom, R. D. Bradley, D. J. Schmidly, C. A. Jones, and R. D. Baker. 1997. Revised checklist of North American mammals north of Mexico. Occas. Papers Mus., Texas Tech Univ., 173: 1-19.

Jones, C. A., J. R. Choate, and H. H. Genoways. 1984. Phylogeny and paleobiogeography of short-tailed shrews (genus *Blarina*) Pp. 56-148, *in* Contributions in Quaternary vertebrate paleontology: a volume in memorial to John E. Guilday (H. H. Genoways and M. R. Dawson, eds.), Spec. Publ. Carnegie Mus. Nat. Hist., 8:v + 1-538.

Jones, J. K., and R. W. Manning. 1990. Additional comments on big brown bats (*Eptesicus fuscus*) from northwestern Texas. Southwestern Nat., 35:342-343.

Jones, J. K., and R. W. Manning.. 1991. Comments on distribution of two species of pocket mice (genus *Chaetodipus*) along the Pecos River, Texas. Texas J. Sci., 43:99-101.

Jones, J. K., Jr., C. Jones, and D. J. Schmidly. 1988*a*. Annotated checklist of Recent land mammals of Texas. Occas. Papers Mus., Texas Tech Univ., 119: 1-26.

Jones, J. K., Jr., R. W. Manning, C. Jones, and R. R. Hollander. 1988*b*. Mammals of the northern Texas Panhandle. Occas. Papers Mus., Texas Tech Univ., 126:1-54.

Jones, J.K., Jr., and C. Jones. 1992. Revised checklist of Recent land mammals of Texas, with annotations. Texas J. Sci., 44:53-74.

Jones, J. K. Jr., R. W. Manning, and J. R. Goetze. 1991. Noteworthy records of seven species of small mammals from west-central Texas. Occas. Papers Mus., Texas Tech Univ., 143:1-4.

Jones J.K., Jr., R. W. Manning, F. D. Yancey, II, and C. Jones. 1993. Records of five species of mammals from western Texas. Texas J. Sci., 45: 104-105.

Jones, J. K., Jr., R. S. Hoffmann, D. W. Rice, C. Jones, R. J. Baker, and M. D. Engstrom. 1992. Revised checklist of North American mammals north of Mexico, 1991. Occas. Papers Mus., Texas Tech Univ., 146:1-23.

Kratochvil, J. 1982. Karyotyp und System der Familie Felidae (Carnivora, Mammalia). Folia Zoologica, 31:289-304.

Lee, T. J., Jr., and M. D. Engstrom. 1991. Genetic variation in the silky pocket mouse (*Perognahus flavus*) in Texas and New Mexico. J. Mamm., 72:273-285.

Lee, T. J., Jr., B. R. Riddle, and P.L. Lee. 1996. Speciation in the desert pocket mouse (*Chaetodipus penicillatus* Woodhouse). J. Mamm., 77:58-68.

Manning, R. W., C. Jones, J. K. Jones, Jr., and R. R. Hollander. 1988. Subspecific status of the pallid bat, *Antrozous pallidus*, in the Texas Panhandle and adjacent areas. Occas. Papers Mus., Texas Tech Univ., 118: 1-5.

Marshall, L. G., J. A. Case, and M. O. Woodburne. 1990. Phylogenetic relationships of the families of marsupials. Pp. 433-505, *in* Current mammalogy (H. H. Genoways, ed.), Plenum Press, New York, 2:xviii + 1-577.

Miller, G. S. Jr., and R. Kellogg. 1955. List of North American recent mammals. Bull. U. S.Nat. Mus., Recent 205:xii+954.

Nedbal, M. A., D. J. Schmidly, and R. D. Bradley. 1994. Records of three species of bats in southeast Texas. Texas J. Sci., 46:195-196.

Owen, J.G., R.J. Baker, and S.L. Williams. 1996. Karyotypic variation in spotted skunks (Carnivora: Mustelidae: *Spilogale*) from Texas, Mexico and El Salvador. Texas J. Sci., 48:119-122.

Qumsiyeh, M. B., C. Sanchez H., K. K. Davis, J. C. Patton, and R. J. Baker. 1988. Chromosomal evolution in *Geomys* as revealed by G- and C-band analysis. Southwestern Nat., 33:1-13.

Roberts, K. J., Yancey, F. D., II, and C. Jones. 1997. Distributional records of small mammals from the Texas Panhandle. Texas J. Sci., 49:57-64.

Rogers, D.S., and D.J. Schmidly. 1981. Geographic variation in the white-throated woodrat (*Neotoma albigula*) from New Mexico, Texas, and northern Mexico. Southwestern Hat., 26:167-181.

Ruedas, L.A. In press. Systematics of *Sylvilagus* Gray, 1867 (Lagomorpha: Leporidae) from southwestern North America. J. Mamm.

Schmidly, D. J. 1983. Texas mammals east of the Balcones Fault Zone. Texas A&M Univ. Press, College Station, xviii + 400 pp.

Schmidly, D. J. 1984. The furbearers of Texas. Bull. Texas Parks Wildlife Dept., 1 1 1:vii + 1-55.

Schmidly, D. J. 1991. The bats of Texas. Texas A&M Univ. Press, College Station, xvii + 188 pp.

Schmidly, D. J., and J. A. Read. 1986. Cranial variation in the bobcat (*Felis rufus*) from Texas and surrounding states. Occas. Papers Mus., Texas Tech Univ., 101:1-39.

Stangl, F. B., Jr. 1992. A new subspecies of the tawny-bellied cotton rat, *Sigmodon fulviventer*, from Trans-Pecos Texas. Occas. Papers Mus., Texas Tech Univ., 145:1-4.

Stangl, F. B., Jr., R. D. Owen, and D. E. Morris-Fuller. 1991. Cranial variation and asymmetry in southern populations of the porcupine, *Erethizon dorsatum*. Texas J. Sci., 43:237-259.

Stangl, F. B. , Jr., and C. B. Carr. 1997. status of *Blarina hylophaga* (Insectivora:Soricidae) in North Texas and Southern Oklahoma. Texas J. Sci., 49:159-162.

Stangl. F. B., Jr., and T. J. McDonough. 1997. Noteworthy records of mammals from Fannin County, Texas, Texas J. Sci., 49:259-261.

Theis, M. 1994. A new record for *Plecotus rafinesquii* (Chiroptera: Vespertilionidae) from East Texas. Texas J. Sci., 46:338-369.

Traweek, M. S. 1985. Statewide census of exotic big game animals. Texas Parks Wildlife Dept., Fed. Aid Proj., W-109 (job no. 21), 40 pp. (processed).

Tumlison, R., and M. D. Douglas. 1992. Parsimony analysis and the phylogeny of Plecotine bats (Chiropters: Vespertilionidae). J. Mamm., 73:276-285.

Walker, C. W., J. K. Sandel, R. L. Honeycutt, and C. Adams. 1996. Winter utilization of box culverts by vespertilionid bats in southeastern Texas. Texas J. Sci., 48:166-170.

Wilson, D. E. 1973. The systematic status of *Perognathus merriami* Allen. Proc. Biol. Soc. Washington, 86:175-192.

Wilson, D. E., and D. M. Reeder (eds). 1993. Mammal Species of the World: a taxonomic and geographic reference. Smithsonian Inst. Press, Washington, D.C, XVIII + 1206 pp.

Yancey, F. D., II, J. R. Goetze, B.M. Garaibeh, and C. Jones. 1995*a*. Distributional records of small mammals from the southwestern Rolling Plains of Texas. Texas J. Sci.,47:101-105.

Yancey, F. D., II, C. Jones, and R. W. Manning. 1995*b*. The eastern pipistrelle, *Pipistrellus subflavus* (Chiroptera: Vespertilionidae) from the Big Bend region of Texas. Texas J. Sci.,47:229-231.

Yancey, F. D. , II. 1997. The mammals of Big Bend Ranch State Park, Texas. Spec. Publ. Mus., Texas Tech Univ., 39:1-210.

Yancey, F. D., and C. Jones. 1996*a*. New county records for ten species of bats (Vespertilionidae and Molossidae) from Texas. Texas J. Sci.,48: 137-142.

Yancey, F. D. , II, and C. Jones. 1996*b*. Notes on three species of small mammals from the Big Bend region of Texas. Texas J. Sci., 48:247-250.

Yancey, F. D., II, R. W. Manning, and C. Jones. 1996*a*. Distribution, natural history and status of the Palo Duro mouse, *Peromyscus truei comanche*, in Texas. Texas J. Sci., 48: 3-12.

Yancey, F. D., II, J. R. Goetze, C. Jones, and R. W. Manning. 1996*b*. The mammals of Justiceburg Wildlife Management Area and adjacent areas, Garza and Kent counties,Texas. Occas. Papers Mus., Texas Tech Univ., 161:1-26.

Yancey, F. D., II, and C. Jones. 1997. Rafinesque's big-eared bats, *Plecotus rafinesquii,* Chiroptera: Vespertilionidae), from Shelby County, Texas. Texas J. Sci., 49:166-167.

Yancey, F.D., II, R.W. Manning, J.R. Goetze, and C. Jones. 1998. The mammals of Lake Meredith National Recreation Area and adjacent areas, Hutchinson, Moore, and Potter counties, Texas. Occas. Papers Mus., Texas Tech Univ., 174:1-20.

Addresses of Authors:

RICHARD W. MANNING

Department of Biology
Southwest Texas StateUniversity
San Marcos, Texas 78666
e-mail: rm11@academia.swt.edu

CLYDE JONES

Department of Biological Sciences and
Museum of Texas Tech University
Mail Stop 3191
Lubbock, Texas 79409-3191
e-mail: cjones@packrat.musm.ttu.edu

PUBLICATIONS OF THE MUSEUM OF TEXAS TECH UNIVERSITY

It was through the efforts of Horn Professor J Knox Jones, as director of Academic Publications, that Texas Tech University initiated several publications series including the Occasional Papers of the Museum. This and future editions in the series are a memorial to his dedication to excellence in academic publications. Professor Jones enjoyed editing scientific publications and served the scientific community as an editor for the Journal of Mammalogy, Evolution, The Texas Journal of Science, Occasional Papers of the Museum, and Special Publications of the Museum. It is with special fondness that we remember Dr. J Knox Jones.

Institutional subscriptions are available through the Museum of Texas Tech University, attn: NSRL Publications Secretary, Box 43191, Lubbock, TX 79409-3191. Individuals may also purchase separate numbers of the Occasional Papers directly from the Museum of Texas Tech University.

ISSN 0149-175X

Museum of Texas Tech University, Lubbock, TX 79409-3191

Great Trinity Forest Management Plan

Wildlife Management

Birds of White Rock Lake and Vicinity

Birds of White Rock Lake and Vicinity

Compiled by Jim Peterson, 1999, 2005, 2005a, 2005b
Contributions by Thomas Riecke and Chris Runk

Nomenclature and Taxonomy Follow the Forty-first Supplement

to the AOU Checklist of North American Birds (AOU 1997)

LEGEND

A Abundant: Should see on every trip in the proper habitat
C Common: Should see on 3 out of 4 trips in the proper habitat
FC Fairly Common: Should see on 2 out of 4 trips in the proper habitat
U Uncommon: Should see on 1 out of 4 trips in the proper habitat
R Rare: Should see on 1 out of 10 trips or less in the proper habitat
I Very irregular: Sometimes occurring only once or twice during a decade

***** Nests in the White Rock Lake vicinity

HABITATS

The Spillway/Fish Hatchery

The Spillway/Fish Hatchery Area is a dam spillway adjoined by a few acres of bottomland habitat. The bottomland area contains man-made fish ponds overgrown with a dense shrub component and some older hardwoods (hackberry, pecan, willow and oak trees). Several trails wind throughout the small woodland.

The habitat here is particularly diverse and maintains the broadest selection of birds around White Rock Lake. In winter, water birds frequent the ponds (dependent on water levels) while sparrows and towhees forage in the shrubs surrounding them. In spring, the area is a small migrant trap and is generally a good place to look for thrushes, wood-warblers, grosbeaks, orioles, and tanagers. In summer, Wood Duck, Barred Owl, Red-shouldered Hawk, Great-crested Flycatcher, and Warbling Vireo have all nested in close proximity of the spillway.

The spillway itself is a very good place to look for sandpipers in migration and gulls in winter. A wide variety of ducks and occasionally pelicans can usually be found by walking the area just above the dam.

West Lawther Drive

A drive from the Fish hatchery area north on West Lawther Drive will hug the western edge of the lake. Beginning at the historic pump house on the northern edge of the dam, one can usually see (or more likely, hear) Monk Parakeets. These birds currently nest in the power poles across from the pump station. Driving north around the edge of the lake, one can usually find a variety of ducks and grebes. At the very northern edge of the lake, bike trails lead north into a thick tangle of hardwoods. This area is good for wood-warblers and other songbirds in migration.

East Lawther Drive

East Lawther Drive is accessible from White Rock Lake Park on the east side of the lake. The drive winds through large pecan and oak trees which are particularly good for migrating warblers and flycatchers during migration and an occasional Eastern Bluebird in spring and summer. The drive ends at Sunset Bay which is an excellent place to look for ducks, gulls, egrets and a variety of songbirds.

Out of range birds or unexpected birds with few known records.

Western Grebe (1 record)
Neotropic Cormorant (1 record)
Black-bellied Whistling-Duck (2 records)
Common Merganser (2 recent records)

Ross's Goose (2 reports presumed to be wild birds)
Piping Plover (1 record)

Black-necked Stilt (1 record)
Willet (1 record)

Jaeger sp. (1 record)

Mew Gull x (possibly hybrid)

Glaucous Gull (at least 1 record)

Thayer's Gull (at least 4 records)

California Gull (at least 3 records)
Laughing Gull (1 record)

Least Tern (pair, 1 record)

Black-legged Kittiwake (1 record)

Whip-poor-will (1 recent record)

Black-chinned Hummingbird (1 record)

Acadian Flycatcher (1 record)
Bell's Vireo (1 record)
Hooded Warbler (1 record)
Vesper Sparrow (1 record)

Lazuli Bunting (1 record)

Western Tanager (1 record on 1997 Christmas Count)

Small Flycatchers at White Rock:

Chris Runk recently did an informal study of the hard-to-identify Traill's complex of empidonax flycatchers around White Rock Lake. Over several years, Chris visually identified 25 birds that fell into the Traill's complex (Willow or Alder flycatcher). Of the ones that called, 17 birds were Alder, 2 birds were Willow, and 6 birds were silent and remained unidentified as to species. Willow is an early fall migrant in Dallas and of the few empids that can be identified in July, most are Willow.

Most other small eastern empid flycatchers can be identified visually, but it's frequently difficult to get an adequate look. Call and song are still preferred as ID characteristics, particularly in Texas where a western empid is still quite possible. Most empids in Dallas Co., are May migrants in spring, but an unusual Yellow-bellied Flycatcher in June is still possible as this species can sometimes be quite late. Acadian Flycatchers might be possible as early as April, but this flycatcher, common to the southern bottomlands, has never been particularly common in Dallas County even though it nests only about 100 miles to the south and east. Most small flycatchers stretch out their fall migration through August and September.

Species	**SP**	**S**	**F**	**W**

Common Loon	R			I
Pied-billed Grebe	C	I	C	C
Horned Grebe	U		U	FC
Eared Grebe	C		U	FC
American White Pelican	C	I	C	C
Neotropic Cormorant		I		
Double-crested Cormorant	A		A	A
American Bittern	R		R	
Least Bittern *	R	R	I	
Great Blue Heron	C	C	C	FC
Great Egret	C	C	C	R
Snowy Egret	C	C	C	
Little Blue Heron	C	C	C	I
Tricolored Heron		R	R	
Cattle Egret	FC	FC	FC	
Green Heron *	C	C	U	
Black-crowned Night-Heron	FC	FC	U	U
Yellow-crowned Night-Heron *	FC	FC	U	I
White Ibis	U	U	U	
White-faced Ibis	I		I	
Black Vulture	U	R	R	I
Turkey Vulture	U	R	U	R
Black-bellied Whistling-Duck*	I	I		
Greater White-fronted Goose	R		R	R
Snow Goose	U		U	U
Canada Goose	FC		U	U
Wood Duck *	FC	U	C	C
Gadwall	C	I	U	C
American Wigeon	C		FC	FC
Mallard *	A	C	A	A
Blue-winged Teal	C	I	C	I
Cinnamon Teal	R			I
Northern Shoveler	A		C	C
Northern Pintail	C		C	U
Green-winged Teal	C		C	C
Canvasback	U		U	U
Redhead	U		U	R
Ring-necked Duck	U		U	U
Greater Scaup	I			I
Lesser Scaup	C		C	C
Surf Scoter			I	I
White-winged Scoter	I		I	I
Oldsquaw	I		I	I

Bufflehead	U		U	C
Common Goldeneye	R		R	R
Hooded Merganser	R		R	R
Red-breasted Merganser	I			I
Ruddy Duck	C	I	A	A
Mississippi Kite	U		U	
Osprey	U		U	I
Bald Eagle	I		I	I
Northern Harrier	U		U	U
Sharp-shinned Hawk	U		U	U
Cooper's Hawk *	U		U	U
Red-shouldered Hawk *	U	U	U	U
Broad-winged Hawk	U		R	
Swainson's Hawk	R	R	R	
Red-tailed Hawk *	C	FC	FC	C
American Kestrel	C	R	U	C
Merlin	I		R	I
Peregrine Falcon	I		I	I
Sora	U		U	U
Purple Gallinule	I	I	I	
Common Moorhen	R	R	R	
American Coot *	A	R	A	A
Black-bellied Plover	R		R	
American Golden-Plover	U		U	
Semipalmated Plover	U		U	
Killdeer *	A	C	A	C
American Avocet	R		R	
Greater Yellowlegs	U	R	R	R
Lesser Yellowlegs	U	R	U	I
Solitary Sandpiper	U		R	
Spotted Sandpiper	C		FC	FC
Marbled Godwit	R		I	
Ruddy Turnstone	R		R	
Semipalmated Sandpiper	U		U	
Western Sandpiper	U		U	I
Least Sandpiper	C	I	C	C
White-rumped Sandpiper	FC			
Baird's Sandpiper	U		U	
Pectoral Sandpiper	C	I	C	
Dunlin	R		R	
Stilt Sandpiper	U		R	
Buff-breasted Sandpiper	R		R	
Short-billed Dowitcher	R		I	

Long-billed Dowitcher	U		U	I
Wilson's Snipe	C		C	U
American Woodcock	I		I	I
Wilson's Phalarope	R		R	
Franklin's Gull	C		C	R
Little Gull				I
Bonaparte's Gull	C		U	C
Ring-billed Gull	C		C	A
Herring Gull	R		R	R
Lesser Black-backed Gull				R
Common Tern	I		I	
Forster's Tern	FC	I	U	FC
Least Tern		I		
Black Tern	U		U	
Rock Dove *	A	A	A	A
White-winged Dove *	C	C	C	C
Mourning Dove *	C	C	C	C
Monk Parakeet *	FC	FC	FC	FC
Black-billed Cuckoo	R			
Yellow-billed Cuckoo *	C	C	U	
Eastern Screech-Owl *	C	C	C	C
Great Horned Owl *	U	U	U	U
Barred Owl *	C	C	C	C
Common Nighthawk *	C	C	C	
Chuck-will's-widow	R		R	
Chimney Swift *	A	A	A	
Ruby-throated Hummingbird *	C	C	C	
Belted Kingfisher *	C	FC	C	U
Red-headed Woodpecker	I	I	I	I
Red-bellied Woodpecker *	A	A	A	A
Yellow-bellied Sapsucker	C		U	FC
Downy Woodpecker *	C	C	C	C
Hairy Woodpecker	I	I	I	I
Northern Flicker	C		C	C
Pileated Woodpecker	I	I	I	I
Olive-sided Flycatcher	U		U	
Eastern Wood-Pewee	C	I	C	
Yellow-bellied Flycatcher	U		U	
Alder Flycatcher	U		I	
Willow Flycatcher	U		I	
Least Flycatcher	C		FC	
Eastern Phoebe *	C	I	C	
Great Crested Flycatcher *	C	C	FC	

Western Kingbird *	C	U	C	
Eastern Kingbird *	C	U	C	
Scissor-tailed Flycatcher *	C	C	FC	
Loggerhead Shrike *	C	C	C	C
White-eyed Vireo	C	U	U	
Blue-headed Vireo	U		U	R
Yellow-throated Vireo	I		I	
Warbling Vireo *	C	C	C	
Philadelphia Vireo	R		I	
Red-eyed Vireo	C		C	
Blue Jay *	A	A	A	A
American Crow *	A	A	A	A
Horned Lark	R		I	I
Purple Martin *	A	A	U	
Tree Swallow	FC		FC	
Northern Rough-winged Swallow *	U	U	U	
Bank Swallow	U		R	
Barn Swallow *	A	C	C	
Cliff Swallow *	U		U	
Carolina Chickadee *	A	A	A	A
Tufted Titmouse *	C	C	C	C
Red-breasted Nuthatch	I		I	I
White-breasted Nuthatch*	R	R	R	U
Brown Creeper	U		U	FC
Carolina Wren *	C	C	C	C
Bewick's Wren *	FC	U	FC	FC
House Wren	FC		FC	U
Winter Wren	FC		FC	U
Sedge Wren	R			R
Marsh Wren	U		U	R
Golden-crowned Kinglet	U		U	FC
Ruby-crowned Kinglet	A		C	C
Blue-gray Gnatcatcher *	C	U	C	R
Eastern Bluebird *	U	U	R	R
Veery	R			
Gray-cheeked Thrush	R			
Swainson's Thrush	A		U	
Hermit Thrush	FC		U	FC
Wood Thrush	I		I	
American Robin *	C	U	C	C
Gray Catbird *?	FC	R	U	I
Northern Mockingbird *	A	A	A	A
Brown Thrasher *	C	U	U	C

European Starling *	A	A	A	A
American Pipit	C		U	FC
Cedar Waxwing	A		C	C
Golden-winged Warbler	I		I	
Blue-Winged Warbler			I	
Tennessee Warbler	U		U	
Orange-crowned Warbler	C		FC	U
Nashville Warbler	C		C	
Northern Parula *	FC	U	R	
Yellow Warbler	C	I	FC	
Chestnut-sided Warbler	U		R	
Magnolia Warbler	U		R	
Yellow-rumped Warbler	A		FC	C
Black-throated Green Warbler	FC		FC	
Blackburnian Warbler	U		I	
Yellow-throated Warbler	R		I	
Pine Warbler				I
Palm Warbler	I		I	
Bay-breasted Warbler	U		R	
Blackpoll Warbler	U			
Cerulean Warbler	I			
Black-and-white Warbler	U	I	U	I
American Redstart	U		U	
Prothonotary Warbler	U	R	I	
Worm-eating Warbler	I		I	
Ovenbird	U		R	
Northern Waterthrush	U		U	
Louisiana Waterthrush	I		I	
Kentucky Warbler	R		R	
Mourning Warbler	C		C	
Common Yellowthroat	C	I	C	R
Wilson's Warbler	C		C	
Canada Warbler	R		R	
Yellow-breasted Chat	C	I	C	
Summer Tanager	FC	R	FC	
Scarlet Tanager	R			
Eastern Towhee	FC		U	FC
Spotted Towhee	FC		U	FC
Chipping Sparrow	U		U	R
Clay-colored Sparrow	U		I	
Field Sparrow	FC		U	FC
Lark Sparrow *	FC	U	U	FC
Savannah Sparrow	U		R	U

Grasshopper Sparrow	R	I	R	
LeConte's Sparrow	U		U	U
Fox Sparrow	FC		U	FC
Song Sparrow	C		FC	C
Lincoln's Sparrow	FC		FC	FC
Swamp Sparrow	FC		FC	FC
White-throated Sparrow	C		C	C
Harris's Sparrow	FC		U	FC
White-crowned Sparrow	U		U	U
Dark-eyed Junco	C		U	A
Northern Cardinal *	A	A	A	A
Rose-breasted Grosbeak	U		I	
Blue Grosbeak	U	U	R	
Indigo Bunting *	C	U	U	
Painted Bunting	U	R	U	
Dickcissel	R		R	I
Bobolink	R		I	
Red-winged Blackbird *	A	A	A	A
Eastern Meadowlark *	A	FC	FC	C
Yellow-headed Blackbird	I	I	I	
Rusty Blackbird	I		I	R
Common Grackle *	A	C	A	A
Great-tailed Grackle *	A	A	A	A
Brown-headed Cowbird *	A	A	A	A
Orchard Oriole	FC	R	R	
Baltimore Oriole *	FC	R	R	
Bullock's Oriole	I		I	
Purple Finch	I			I
House Finch *	C	FC	C	C
Pine Siskin	I			I
American Goldfinch	A		C	A
House Sparrow *	A	A	A	A

Great Trinity Forest Management Plan

Wildlife Management

Dallas County Christmas Bird Count 2007

	Observed	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12	Total #
Common Loon	CW			1										1
Pied-billed Grebe	Y	5	7	5	2	1		4	1	6	4		1	36
Horned Grebe	Y		2	6										8
Eared Grebe														0
American White Pelican	Y		3	33							44			80
Double-crested Cormorant	Y	53	2555	3500				367			12		35	6522
Neotropic Cormorant	Y			2										2
Great Blue Heron	Y	5	5	5	2	1	1	8	1	9	3		7	47
Little Blue Heron *														0
Great Egret	Y	3	11	10	17			32	2	3	3		8	89
Snowy Egret *														0
Black-crowned Night-Heron	Y		16											16
Yellow-crowned Night Heron														0
Turkey Vulture	Y	1		2	1			5	2	7	2			20
Black Vulture	Y			2				1						3
Snow Goose	Y			1										1
Canada Goose	Y					7								7
Greater White-fronted Goose	Y			45										45
Black-bellied Whistling-Duck														0
Wood Duck	Y	4	4	23	3				2		1			37
Gadwall	Y	19	7	8				35		40			2	111
American Wigeon	Y		2	2	216	117	4	55	12		2			410
Mallard	Y	29	94	100		66	302	202	23	50	103		34	1003
Northern Shoveler	Y	8	15	4	11	80		5			120		30	273
Northern Pintail	Y			7										7
Green-winged Teal	Y			6						10	8			24
Canvasback														0
Redhead														0
Ring-necked Duck	Y	1	1			12	1	1						16
Greater Scaup	Y			2										2
Lesser Scaup	Y		9	12	4	70	10	70	17		8		25	225
Bufflehead	Y		9	4									8	21
Common Goldeneye	Y		3	3										6
Hooded Merganser	Y	1												1

Red-breasted Merganser	Y			6										6
Common Merganser														0
Ruddy Duck	Y		19	13	1	4					1		1	39
Bald Eagle														0
Osprey														0
Northern Harrier														0
Sharp-shinned Hawk	Y			1			1	1	1					4
Cooper's Hawk	Y		1	1		1	4				1			8
Red-shouldered Hawk	Y	1	4	4	2			2	1		2			16
Red-tailed Hawks	Y	8	3	4	2	3	8	10	1	5	5		2	51
generic														
Krider's														
Harlan's														
American Kestrel	Y	3	1	4	1		1	4		3	8		1	26
Merlin														0
Peregrine Falcon	Y			1	1						1			3
Northern Bobwhite														0
American Coot	Y	19	30	127	1	23		10	4	24	1		48	287
Sandhill Crane														0
Killdeer	Y	23	1	10	2	1	3	1	2	1	5			49
Greater Yellowlegs	Y							3		1	5			9
Lesser Yellowlegs														0
Spotted Sandpiper	Y		2								1			3
Least Sandpiper	Y										30			30
Common Snipe	Y	2								2				4
American Woodcock	Y							2						2
Bonaparte's Gull	Y	12	60	30							6			108
Laughing Gull*														0
Franklin's Gull	Y			1										1
Ring-billed Gull	Y	323	340	391		3	12	46	57	42	445		70	1729
California Gull*														0
Herring Gull	Y			1										1
Thayer's Gull*														0
Lesser Black-backed Gull														0
Forster's Tern	Y		5	2										7
Rock Pigeon	Y	117	15	96	176	44	1139	72	120	72	129	200	161	2341
Mourning Dove	Y	4	8	43	8	9	80	120	9	30	66	23	22	422

Eurasian Collared-Dove	Y									1				1
White-winged Dove	Y	3	27	180	48		98	1			21	1	8	387
Inca Dove														0
Monk Parakeet	Y		13	12										25
Barn Owl														0
Eastern Screech-Owl	Y		1	3			1							5
Great Horned Owl														0
Barred Owl	Y		3	1										4
Selasphorus Hummingbird	Y			1										1
Belted Kingfisher	Y		1	1		1	1	1	2		1			8
Red Headed Woodpecker														0
Red-bellied Woodpecker	Y	3	9	39	12	11	6	7	11	3	3	1	2	107
Yellow-bellied Sapsucker	Y	1	1	7		1	3	2	2		3			20
Ladder-backed Woodpecker	Y							1						1
Downy Woodpecker	Y	5	3	26	13	5	2	2	6		1	1	2	66
Hairy Woodpecker	Y				1									1
Northern Flicker	Y		10	12	1	2	4	6	6		4			45
Yellow-shafted														
Red-shafted														
Eastern Phoebe	Y	3	3	3	1						7	1		18
Loggerhead Shrike	Y									1	1			2
Blue-headed Vireo	Y		1	3										4
Blue Jay	Y	24	15	26	12	17	17	1	23	6	7	4	5	157
American Crow	Y	9	6	28	15	4	20	13	8	4	27	2	4	140
Horned Lark														0
Carolina Chickadee	Y	16	16	30	22	4		8	19	4	7		8	134
Tufted Titmouse	Y	15	3	22	3	5		2	4					54
Red-breasted Nuthatch	Y		1	4		1	2	1	3		2		1	15
White-breasted Nuthatch														0
Brown Creeper	Y		2	4		1	2		8		2			19
Carolina Wren	Y	5	11	25	11	3	4	6	9	1	10		1	86
Bewick's Wren														0
House Wren														0
Winter Wren	Y		1	3										4

Sedge Wren														0
Marsh Wren														0
Golden-crowned Kinglet	Y		1	2										3
Ruby-crowned Kinglet	Y	13	18	35		12	7	6	6	2	8	1	3	111
Blue-gray Gnatcatcher	Y			2	2									4
Eastern Bluebird	Y							6						6
Hermit Thrush	Y		2								1			3
American Robin	Y	73	9	2	18	5	90		13		2		20	232
Northern Mockingbird	Y	13	4	14	1	9	9	9	8	4	7	2	4	84
Brown Thrasher	Y		1	6		2	1				1	1		12
European Starling	Y	557	9	700	148	125	117	92	50	30	4000	5	23	5856
American Pipit	Y										1			1
Cedar Waxwing	Y	131	40	275	31	46	625		235		90		125	1598
Orange-crowned Warbler	Y	2	2	19	1	3	1	1	1			1		31
Yellow-rumped Warbler	Y	22	98	91	48	6	30	35	22	12	70			434
Pine Warbler	Y			1			1	1	3					6
Black-and-White Warbler														0
Common Yellowthroat														0
Eastern Towhee	Y		1											1
Spotted Towhee	Y		2											2
Chipping Sparrow	Y							1					7	8
Field Sparrow	Y	7	1	29						12	1			50
Vesper Sparrow														0
Lark Sparrow														0
Savannah Sparrow	Y	24		2						4				30
LeConte's Sparrow	Y			3										3
Fox Sparrow	Y		2					2					1	5
Song Sparrow	Y	1	7	12				2		4	2			28
Lincoln's Sparrow	Y		1	2										3
Swamp Sparrow	Y			2										2
White-throated Sparrow	Y	23	23	112		37	28	13			15	3	30	284
Harris's Sparrow	Y									2				2
White-crowned Sparrow	Y							3		6				9

Dark-eyed Junco	Y	14	8	56	7		19	8	8		8	7	9	144
Slate-colored														
Oregon														
Pink-sided							2							
Lapland Longspur														0
Northern Cardinal	Y	25	15	46	18	9	8	13	12	16	26	2	4	194
Red-winged Blackbird	Y	250	98	397	358	165			14	225	1200		3	2710
Eastern Meadowlark														0
Western Meadowlark														0
Rusty Blackbird														0
Brewer's Blackbird														0
Common Grackle	Y	15	100	402	2	2		6	12					539
Great-tailed Grackle	Y	193	18	400	161	130	173	99	22	52	60	30	75	1413
Brown-headed Cowbird	Y			41				4						45
Purple Finch														0
House Finch	Y		4	16	36	3		53	4		70			186
Pine Siskin														0
American Goldfinch	Y		28	202	14	79	2	14	8	12	35			394
House Sparrow	Y	4	2	15	3	22	42	12	6		10	15	5	136
* = details may be requested														
Duck sp.							4						3	7
Buteo sp.														0
Accipiter sp.							1			3				4
Yellowleg sp.														0
Peep sp.														0
Sparrow sp.														0
Longspur sp.														0
Blackbird sp.			1700				160							1860
Meadowlark sp.	Y	37						4		24				65
Total Species	1													
Count Day	108													
Count Week	109													
Count Day + Species	**109**													

Count Week + Species	**110**													

TEXAS PARKS AND WILDLIFE

BIRDS of the OAKS & PRAIRIES AND OSAGE PLAINS OF TEXAS

BY BRUSH FREEMAN

A Field Checklist

Cover: Illustration of Dickcissel and Red-headed Woodpecker by Rob Fleming. This checklist is dedicated to Rob who died before this checklist was printed. His artwork has graced many of the department's bird publications for years. He will be missed.

Birds of the Oaks and Prairies and Osage Plains of Texas: A Field Checklist

INTRODUCTION

The areas covered in this checklist include a rich birdlife from the western edge of the more eastern forested areas gradually changing to a more western grassland influence (Fig. 1). These two ecoregions are commonly known by other names; for example, the Oaks and Prairies refer to both the Post Oak Belt or Post Oak Savannah and the Blackland Prairie (including the Grand Prairie). The Osage Plains is commonly referred to as the (Western) Cross Timbers. Examples of some of the subregions in this coverage area include The Lost Pines, a variety of smaller prairies including the Grand Prairie, Fayette Prairie, and San Antonio Prairie. For a brief yet excellent description of the major plant communities, please see pages 14-16 in *Texas Wildscapes: Gardening for Wildlife* by Noreen Damude and Kelly Conrad Bender published in 1999 by Texas Parks and Wildlife Press (ISBN: 1-885696-30-2). A total of 471 species has been documented within the two combined areas. Since these areas lie almost in the middle of Texas and extend mostly in a north-south fashion, the avifauna is truly diverse. This checklist is the first of its kind for the coverage area and uses ecological boundaries instead of political ones. The checklist follows the nomenclature and taxonomy as published in the 7th edition of the A.O.U. *Check-list of North American Birds* (1998) and its supplements.

Figure 1. Coverage area of this checklist

There is no shortage of open water in the region due to a large number of manmade reservoirs. There are dozens of such impoundments, most of which occur in the north-east part of the coverage area. These bodies of water have produced some of the most surprising records in the region; products of an altered ecosystem.

A number of species in this checklist are considered very local or confined to either a southern or northern extreme. For example, Brown-crested Flycatchers will only be found in the southern portion of the coverage area, while American Tree Sparrows or Horned Grebes are primarily found in the northern part. It is also important to understand that most birds show preferences for specific habitat types; a good working knowledge of these preferences will provide the observer the ability to master the birds of the area.

A wide variety of published material was used to construct this booklet, including local bird checklists, published materials, records published in ABA's North American Birds (formerly Field Notes), the Texas On-line Clearinghouse www.texasbirding.net/txclrhouse/, many personal communications with other area-experts, and information provided by the Texas Bird Records Committee. Almost 35 years of birding experience in the region by the author was also used to develop this checklist. The abundance codes for some species are subjective evaluations where published data were insufficient.

ACKNOWLEDGMENTS

This is the fifth ecoregional bird checklist for Texas in a series initiated by Texas Partners in Flight under the direction of Cliff Shackelford at Texas Parks and Wildlife Department. The following reviewers commented on an early version of this checklist: Fred Collins, Bert Frenz, Cliff Shackelford, and Ken Steigman. Also of great assistance in the development of this checklist were Keith Arnold, Kelly Cotten, Tim Fennell, Jeff Hanson, Mark Lockwood, Willie Sekula, and Matt White. We thank the Migratory Bird Office, Region 2 of the U.S. Fish and Wildlife Service for support.

LEGEND

Abundant ....

Common ....

Uncommon ....

Rare ....

Very rare to casual ....

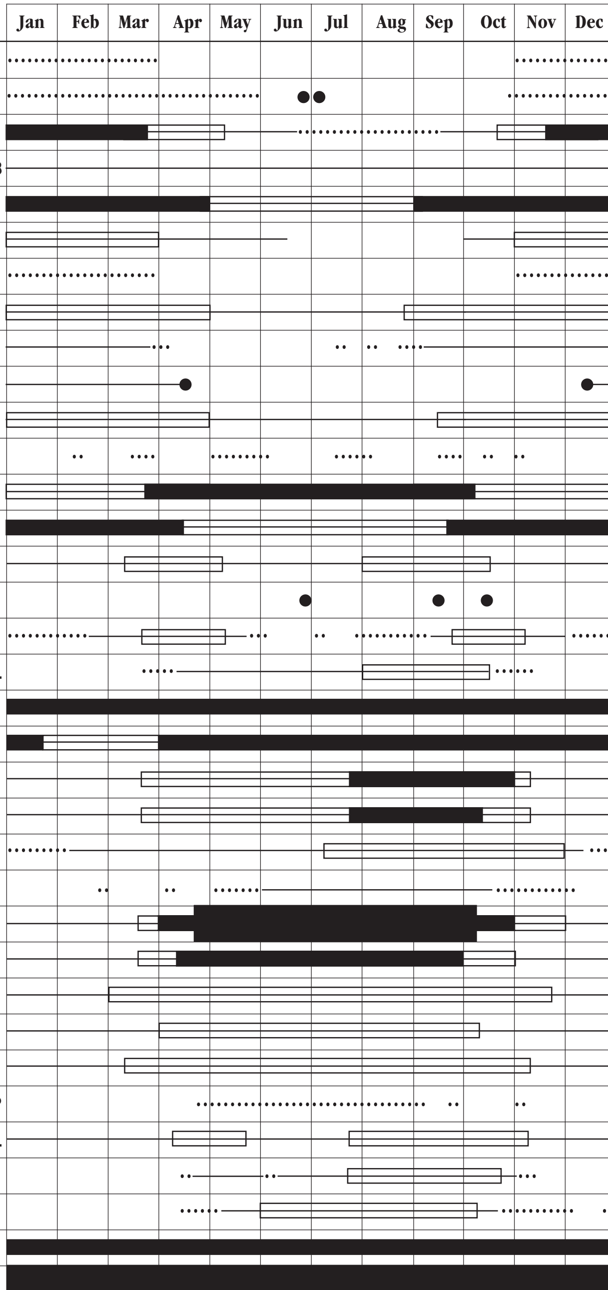
Accidental or single occurrence .... ●

Lingering single occurrence .... ●—●

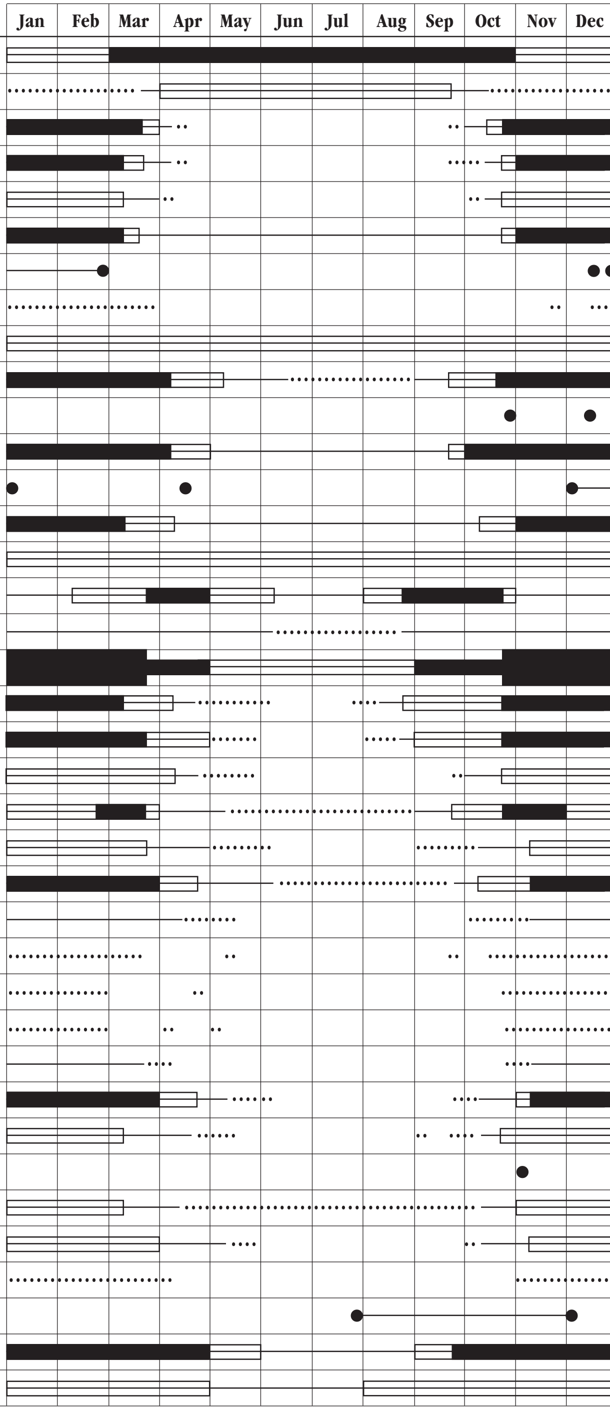
B Breeds or has bred in area covered by this checklist
B? Breeding suspected or questionable
I Introduced
N Primarily found only in the northern portion of region
S Primarily found only in the southern portion of region
W Primarily found only in the western portion of region
NW Primarily found only in the northwestern portion of region
L Found or breeds very locally
H Historic records apply

CHECKLIST

Species	
___Red-throated Loon	N
___Pacific Loon	N
___Common Loon	
___Least Grebe	SB
___Pied-billed Grebe	B
___Horned Grebe	N
___Red-necked Grebe	N
___Eared Grebe	
___Western Grebe	
___Blue-footed Booby	
___American White Pelican	
___Brown Pelican	
___Neotropic Cormorant	B
___Double-crested Cormorant	B
___Anhinga	B
___Magnificent Frigatebird	
___American Bittern	
___Least Bittern	BL
___Great Blue Heron	B
___Great Egret	B
___Snowy Egret	B
___Little Blue Heron	B
___Tricolored Heron	B
___Reddish Egret	S
___Cattle Egret	B
___Green Heron	B
___Black-crowned Night-Heron	B
___Yellow-crowned Night-Heron	B
___White Ibis	B
___Glossy Ibis	B?
___White-faced Ibis	BL
___Roseate Spoonbill	
___Wood Stork	
___Black Vulture	B
___Turkey Vulture	B

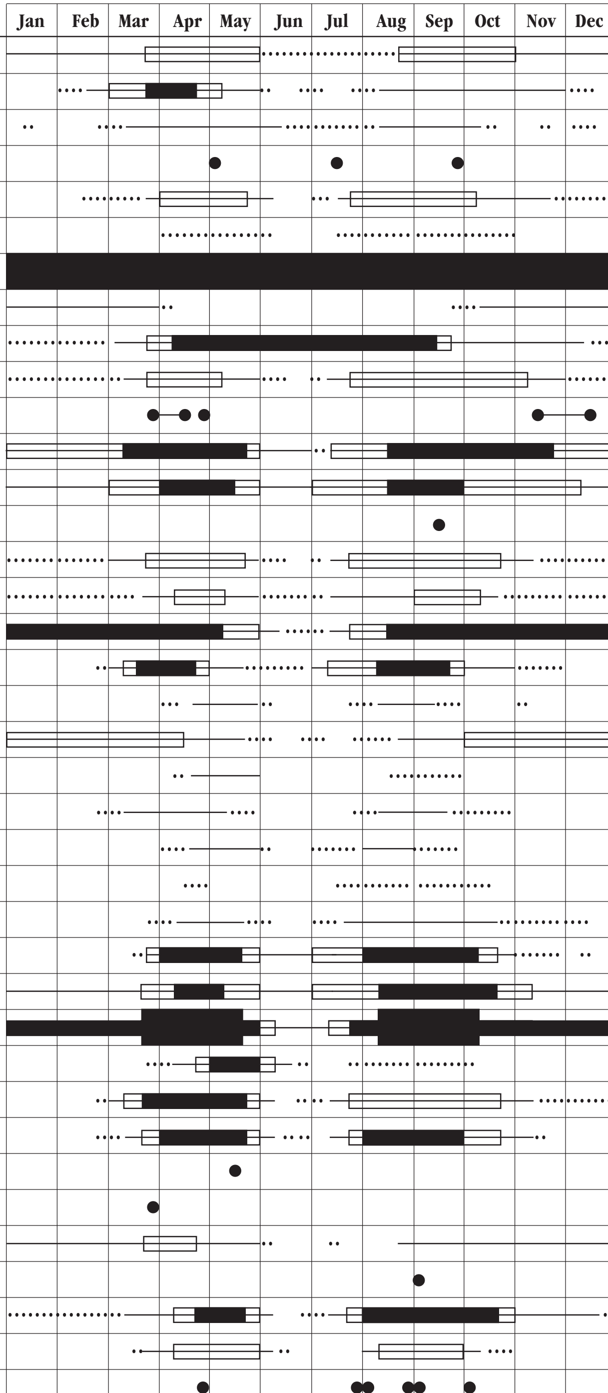


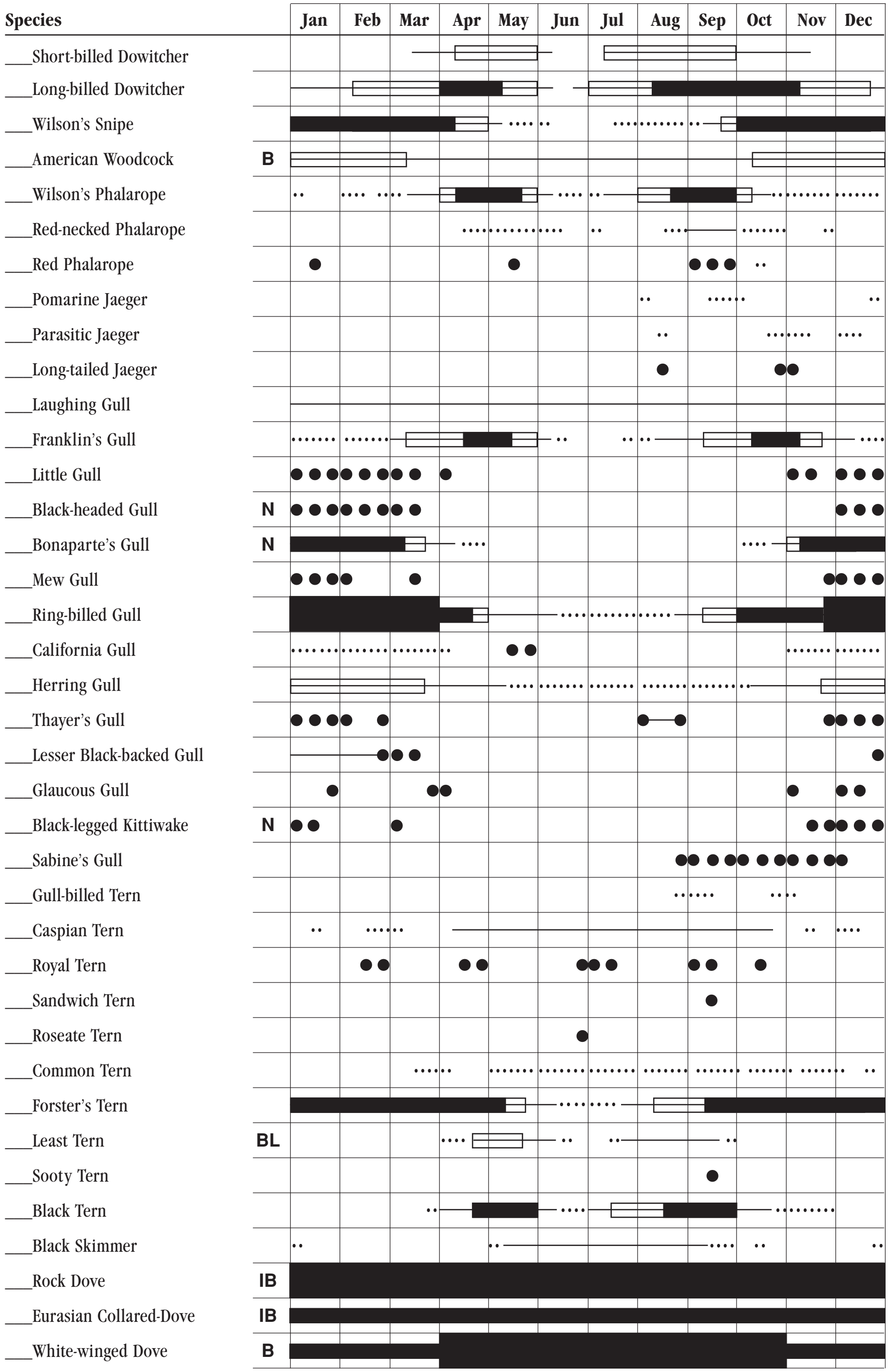
Species	
___Black-bellied Whistling-Duck	B
___Fulvous Whistling-Duck	SB
___Greater White-fronted Goose	
___Snow Goose	
___Ross's Goose	
___Canada Goose	NB
___Brant	
___Tundra Swan	
___Wood Duck	B
___Gadwall	
___Eurasian Wigeon	
___American Wigeon	
___American Black Duck	
___Mallard	NB
___Mottled Duck	B
___Blue-winged Teal	B
___Cinnamon Teal	S
___Northern Shoveler	
___Northern Pintail	
___Green-winged Teal	
___Canvasback	
___Redhead	
___Ring-necked Duck	
___Lesser Scaup	
___Greater Scaup	
___Surf Scoter	
___White-winged Scoter	
___Black Scoter	
___Long-tailed Duck	
___Bufflehead	
___Common Goldeneye	N
___Barrow's Goldeneye	
___Hooded Merganser	B
___Red-breasted Merganser	N
___Common Merganser	NW
___Masked Duck	
___Ruddy Duck	BL
___Osprey	



Species		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
___Swallow-tailed Kite	SBH												
___Mississippi Kite	B												
___White-tailed Kite	B												
___Bald Eagle	BL												
___Northern Harrier	NB												
___Sharp-shinned Hawk	B?												
___Cooper's Hawk	BL												
___Northern Goshawk													
___Harris's Hawk	SB												
___Red-shouldered Hawk	B												
___Broad-winged Hawk	BL												
___Swainson's Hawk	NB												
___White-tailed Hawk	SB												
___Zone-tailed Hawk	W												
___Red-tailed Hawk	B												
___Ferruginous Hawk													
___Rough-legged Hawk	N												
___Golden Eagle	W												
___Crested Caracara	B												
___American Kestrel	BL												
___Merlin													
___Peregrine Falcon													
___Prairie Falcon	NW												
___Ring-necked Pheasant	IBL												
___Wild Turkey	BL												
___Scaled Quail	NWB												
___Northern Bobwhite	B												
___Yellow Rail													
___Black Rail													
___King Rail	BL												
___Virginia Rail	BL												
___Sora													
___Paint-billed Crake													
___Purple Gallinule	BL												
___Common Moorhen	B												
___American Coot	BL												
___Sandhill Crane	S												
___Whooping Crane													

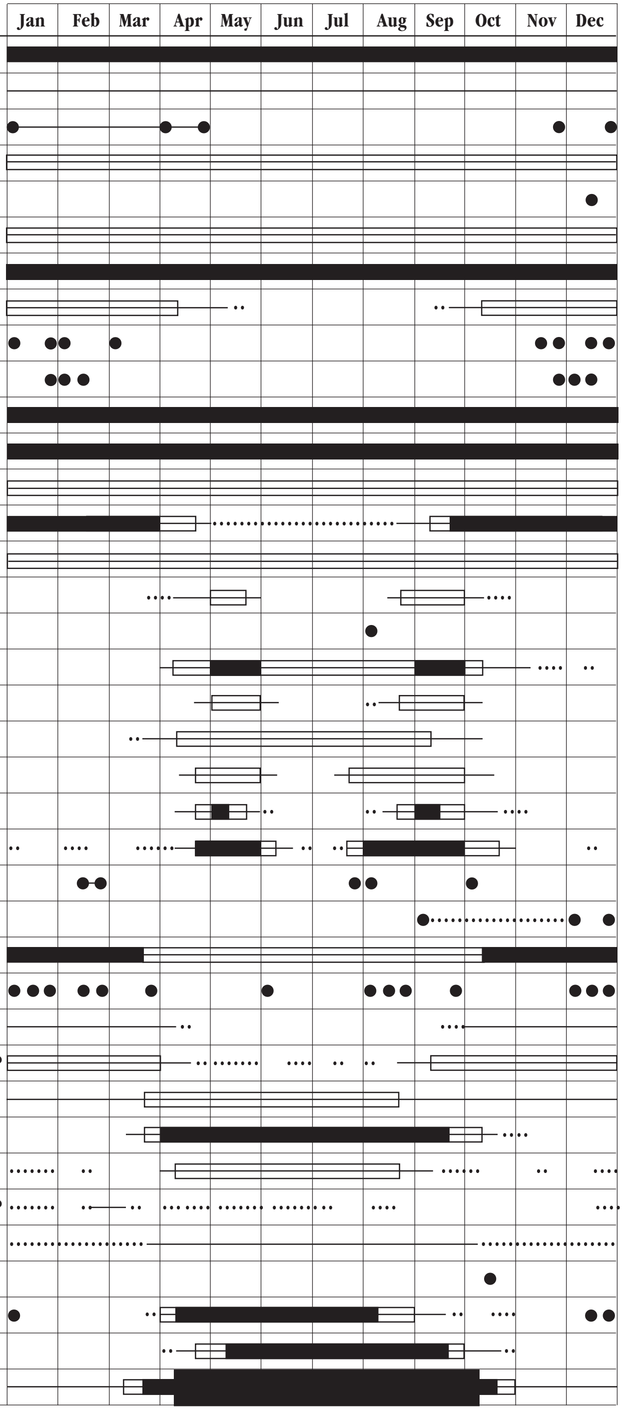
Species		
___Black-bellied Plover		
___American Golden-Plover		
___Snowy Plover		
___Wilson's Plover		
___Semipalmated Plover		
___Piping Plover		
___Killdeer	B	
___Mountain Plover	W	
___Black-necked Stilt	B	
___American Avocet		
___Northern Jacana		
___Greater Yellowlegs		
___Lesser Yellowlegs		
___Spotted Redshank		
___Solitary Sandpiper		
___Willet		
___Spotted Sandpiper		
___Upland Sandpiper		
___Whimbrel		
___Long-billed Curlew		
___Hudsonian Godwit		
___Marbled Godwit		
___Ruddy Turnstone		
___Red Knot		
___Sanderling		
___Semipalmated Sandpiper		
___Western Sandpiper		
___Least Sandpiper		
___White-rumped Sandpiper		
___Baird's Sandpiper		
___Pectoral Sandpiper		
___Sharp-tailed Sandpiper		
___Purple Sandpiper		
___Dunlin		
___Curlew Sandpiper		
___Stilt Sandpiper		
___Buff-breasted Sandpiper		
___Ruff		

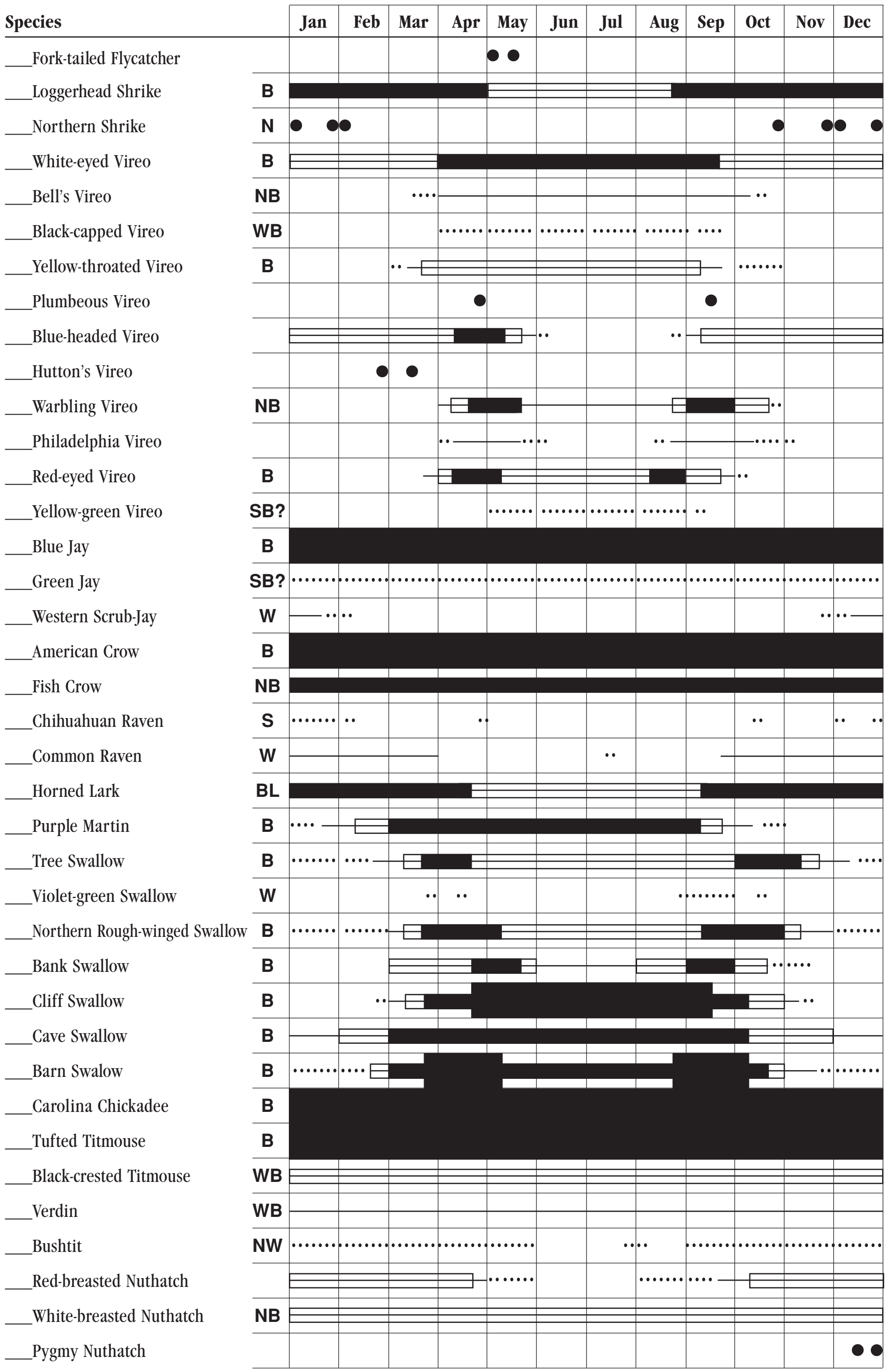



Species
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
___Short-billed Dowitcher
___Long-billed Dowitcher
___Wilson's Snipe
___American Woodcock B
___Wilson's Phalarope
___Red-necked Phalarope
___Red Phalarope
___Pomarine Jaeger
___Parasitic Jaeger
___Long-tailed Jaeger
___Laughing Gull
___Franklin's Gull
___Little Gull
___Black-headed Gull N
___Bonaparte's Gull N
___Mew Gull
___Ring-billed Gull
___California Gull
___Herring Gull
___Thayer's Gull
___Lesser Black-backed Gull
___Glaucous Gull
___Black-legged Kittiwake N
___Sabine's Gull
___Gull-billed Tern
___Caspian Tern
___Royal Tern
___Sandwich Tern
___Roseate Tern
___Common Tern
___Forster's Tern
___Least Tern BL
___Sooty Tern
___Black Tern
___Black Skimmer
___Rock Dove IB
___Eurasian Collared-Dove IB
___White-winged Dove B

Species		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
____Mourning Dove	B												
____Inca Dove	B												
____Common Ground-Dove	SB												
____White-tipped Dove													
____Monk Parakeet	IBL												
____Black-billed Cuckoo													
____Yellow-billed Cuckoo	B												
____Greater Roadrunner	B												
____Groove-billed Ani	SB												
____Barn Owl	B												
____Eastern Screech-Owl	B												
____Great Horned Owl	B												
____Snowy Owl													
____Burrowing Owl	BH												
____Barred Owl	B												
____Long-eared Owl	N												
____Short-eared Owl													
____N. Saw-whet Owl													
____Lesser Nighthawk	SB?												
____Common Nighthawk	B												
____Common Pauraque	S												
____Common Poorwill	WB												
____Chuck-will's-widow	B												
____Whip-poor-will	B?												
____Chimney Swift	B												
____White-throated Swift													
____Green Violet-ear													
____Broad-billed Hummingbird													
____Buff-bellied Hummingbird	SB?												
____Blue-throated Hummingbird													
____Ruby-throated Hummingbird	B												
____Black-chinned Hummingbird	WB												
____Anna's Hummingbird													
____Calliope Hummingbird													
____Broad-tailed Hummingbird													
____Rufous Hummingbird													
____Allen's Hummingbird													
____Ringed Kingfisher	B?												

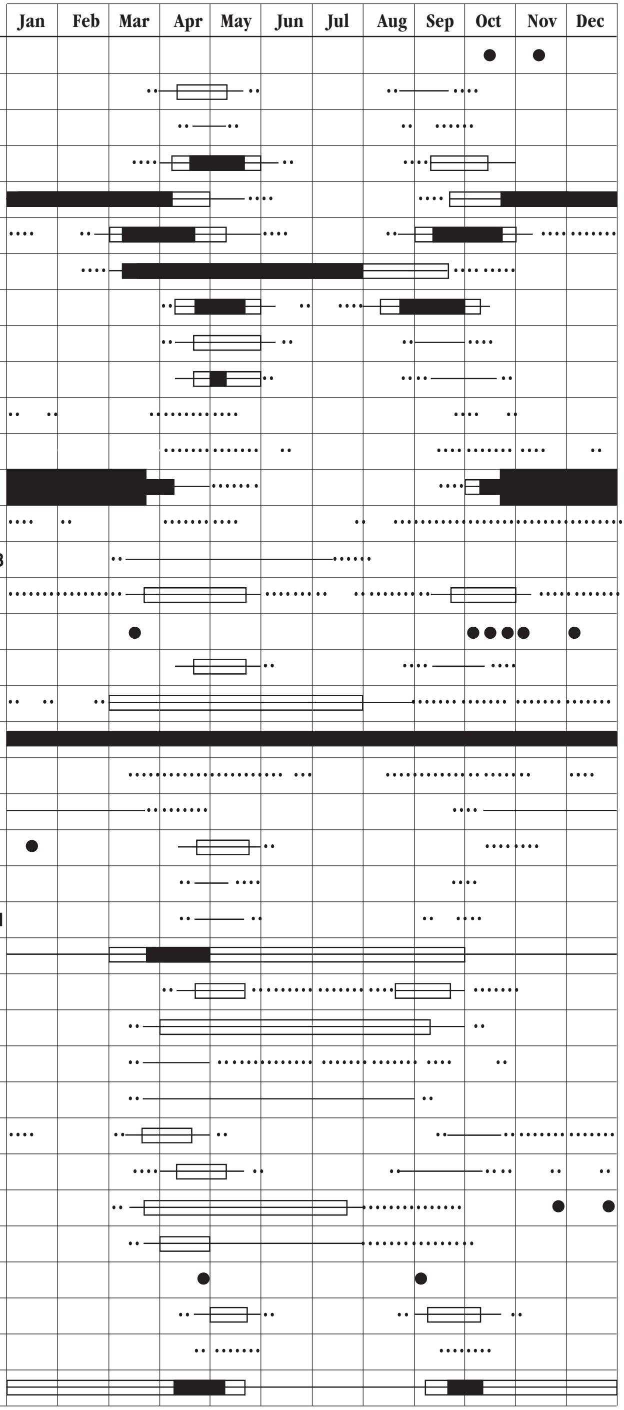
Species	
___Belted Kingfisher	NB
___Green Kingfisher	SB
___Lewis's Woodpecker	
___Red-headed Woodpecker	NB
___Acorn Woodpecker	
___Golden-fronted Woodpecker	SB
___Red-bellied Woodpecker	B
___Yellow-bellied Sapsucker	
___Red-naped Sapsucker	
___Williamson's Sapsucker	
___Ladder-backed Woodpecker	WB
___Downy Woodpecker	B
___Hairy Woodpecker	BL
___Northern Flicker	BL
___Pileated Woodpecker	B
___Olive-sided Flycatcher	
___Western Wood-Pewee	
___Eastern Wood-Pewee	B
___Yellow-bellied Flycatcher	
___Acadian Flycatcher	B
___Alder Flycatcher	
___Willow Flycatcher	
___Least Flycatcher	
___Hammond's Flycatcher	
___"Western" Flycatcher	
___Eastern Phoebe	B
___Black Phoebe	
___Say's Phoebe	NW
___Vermilion Flycatcher	SB?
___Ash-throated Flycatcher	SB
___Great Crested Flycatcher	B
___Brown-crested Flycatcher	SB
___Great Kiskadee	SB?
___Couch's Kingbird	SB
___Cassin's Kingbird	
___Western Kingbird	B
___Eastern Kingbird	B
___Scissor-tailed Flycatcher	B




Species
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
___Fork-tailed Flycatcher
___Loggerhead Shrike B
___Northern Shrike N
___White-eyed Vireo B
___Bell's Vireo NB
___Black-capped Vireo WB
___Yellow-throated Vireo B
___Plumbeous Vireo
___Blue-headed Vireo
___Hutton's Vireo
___Warbling Vireo NB
___Philadelphia Vireo
___Red-eyed Vireo B
___Yellow-green Vireo SB?
___Blue Jay B
___Green Jay SB?
___Western Scrub-Jay W
___American Crow B
___Fish Crow NB
___Chihuahuan Raven S
___Common Raven W
___Horned Lark BL
___Purple Martin B
___Tree Swallow B
___Violet-green Swallow W
___Northern Rough-winged Swallow B
___Bank Swallow B
___Cliff Swallow B
___Cave Swallow B
___Barn Swallow B
___Carolina Chickadee B
___Tufted Titmouse B
___Black-crested Titmouse WB
___Verdin WB
___Bushtit NW
___Red-breasted Nuthatch
___White-breasted Nuthatch NB
___Pygmy Nuthatch

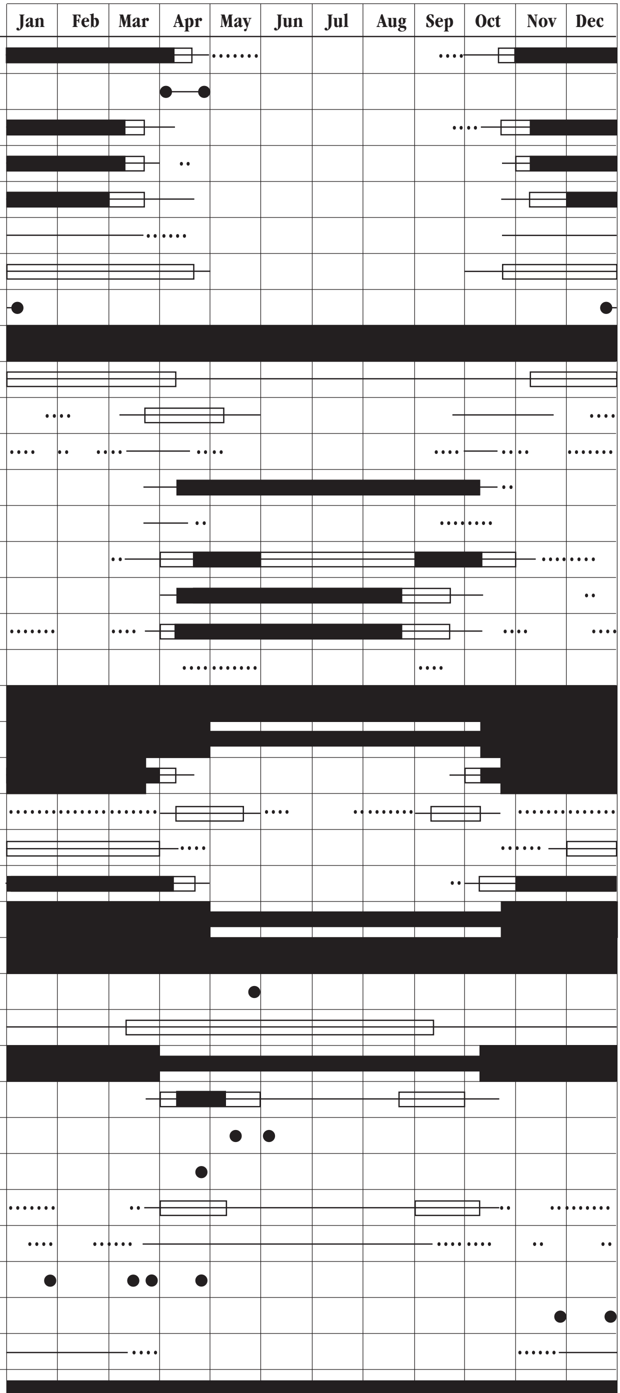
Species		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
___Brown-headed Nuthatch	NB												
___Brown Creeper													
___Cactus Wren	SB?												
___Rock Wren	WB?												
___Canyon Wren	NWB												
___Carolina Wren	B												
___Bewick's Wren	B												
___House Wren													
___Winter Wren													
___Sedge Wren													
___Marsh Wren	BL												
___American Dipper													
___Golden-crowned Kinglet													
___Ruby-crowned Kinglet													
___Blue-gray Gnatcatcher	B												
___Eastern Bluebird	B												
___Western Bluebird	W												
___Mountain Bluebird	W												
___Townsend's Solitaire	W												
___Veery													
___Gray-cheeked Thrush													
___Swainson's Thrush													
___Hermit Thrush													
___Wood Thrush	BL												
___Clay-colored Robin													
___American Robin	B												
___Varied Thrush													
___Gray Catbird	NB												
___Northern Mockingbird	B												
___Sage Thrasher	B												
___Brown Thrasher	NB												
___Long-billed Thrasher	SB												
___Curve-billed Thrasher	WB												
___European Starling	B												
___American Pipit													
___Sprague's Pipit													
___Bohemian Waxwing													
___Cedar Waxwing													

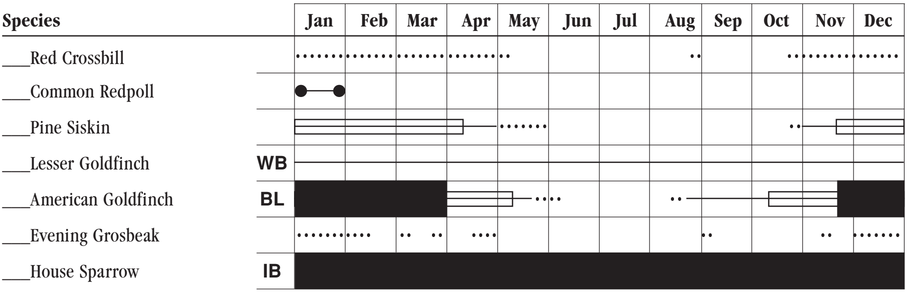
Species	
___Phainopepla	
___Blue-winged Warbler	
___Golden-winged Warbler	
___Tennessee Warbler	
___Orange-crowned Warbler	
___Nashville Warbler	
___Northern Parula	B
___Yellow Warbler	B?
___Chestnut-sided Warbler	
___Magnolia Warbler	
___Cape May Warbler	
___Black-throated Blue Warbler	
___Yellow-rumped Warbler	
___Black-throated Gray Warbler	
___Golden-cheeked Warbler	NWB
___Black-throated Green Warbler	
___Townsend's Warbler	
___Blackburnian Warbler	
___Yellow-throated Warbler	NB
___Pine Warbler	BL
___Prairie Warbler	B?
___Palm Warbler	
___Bay-breasted Warbler	
___Blackpoll Warbler	
___Cerulean Warbler	B?H
___Black-and-white Warbler	B
___American Redstart	BH
___Prothonotary Warbler	BL
___Worm-eating Warbler	BL
___Swainson's Warbler	BL
___Ovenbird	
___Northern Waterthrush	
___Louisiana Waterthrush	BL
___Kentucky Warbler	BL
___Connecticut Warbler	
___Mourning Warbler	
___MacGillivray's Warbler	W
___Common Yellowthroat	B



Species		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
___Hooded Warbler	BL												
___Wilson's Warbler													
___Canada Warbler													
___Red-faced Warbler													
___Yellow-breasted Chat	BL												
___Hepatic Tanager													
___Summer Tanager	B												
___Scarlet Tanager													
___Western Tanager													
___Olive Sparrow	SB?												
___Green-tailed Towhee	W												
___Eastern Towhee													
___Spotted Towhee	W												
___Canyon Towhee	NWB												
___Bachman's Sparrow	BL												
___Cassin's Sparrow	SB												
___Rufous-crowned Sparrow	NWB												
___American Tree Sparrow	N												
___Chipping Sparrow	B												
___Clay-colored Sparrow	W												
___Brewer's Sparrow													
___Field Sparrow	NWB												
___Vesper Sparrow													
___Lark Sparrow	B												
___Black-throated Sparrow	NWB												
___Lark Bunting	W												
___Savannah Sparrow													
___Baird's Sparrow													
___Grasshopper Sparrow	BL												
___Henslow's Sparrow	L												
___Le Conte's Sparrow													
___Nelson's Sharp-tailed Sparrow	L												
___Fox Sparrow													
___Song Sparrow													
___Lincoln's Sparrow													
___Swamp Sparrow													
___White-throated Sparrow													
___Harris's Sparrow													

Species	
___White-crowned Sparrow	
___Golden-crowned Sparrow	
___Dark-eyed Junco	
___McCown's Longspur	W
___Lapland Longspur	
___Smith's Longspur	N
___Chestnut-collared Longspur	W
___Snow Bunting	
___Northern Cardinal	B
___Pyrrhuloxia	SB
___Rose-breasted Grosbeak	
___Black-headed Grosbeak	
___Blue Grosbeak	B
___Lazuli Bunting	W
___Indigo Bunting	B
___Painted Bunting	B
___Dickcissel	B
___Bobolink	
___Red-winged Blackbird	B
___Eastern Meadowlark	B
___Western Meadowlark	W
___Yellow-headed Blackbird	
___Rusty Blackbird	N
___Brewer's Blackbird	W
___Common Grackle	B
___Great-tailed Grackle	B
___Shiny Cowbird	
___Bronzed Cowbird	SB
___Brown-headed Cowbird	B
___Orchard Oriole	B
___Hooded Oriole	
___Audubon's Oriole	
___Baltimore Oriole	NB
___Bullock's Oriole	WB
___Scott's Oriole	
___Pine Grosbeak	
___Purple Finch	N
___House Finch	B





LEGEND

Abundant ....

Common ....

Uncommon ....

Rare ....

Very rare to casual ....

Accidental or single occurrence ....

Lingering single occurrence ....

B Breeds or has bred in area covered by this checklist

B? Breeding suspected or questionable

I Introduced

N Primarily found only in the northern portion of region

S Primarily found only in the southern portion of region

W Primarily found only in the western portion of region

NW Primarily found only in the northwestern portion of region

L Found or breeds very locally

H Historic records apply

The following two Review Species were reported in the region prior to the creation of the Texas Bird Records Committee or were never submitted to this committee for review. Some of these reports likely represent valid records.

- Trumpeter Swan (undocumented report in 1867)
- Black-billed Magpie (undocumented reports in 1946, 1954, 1973, and 1990)

The following list includes Hypothetical Species that may appear in the region or have previously been reported without supporting documentation. A number of these species have occurred adjacent to the coverage area of this checklist.

Clark's Grebe
Common Black-Hawk
Band-tailed Pigeon
Vaux's Swift
Dusky Flycatcher
Gray Flycatcher
Cassin's Vireo
Clark's Nutcracker
Tropical Parula
Hermit Warbler
Black-chinned Sparrow
Varied Bunting
Boat-tailed Grackle
Cassin's Finch

Extinct or extirpated species from the checklist area:

Greater Prairie-Chicken
Lesser Prairie-Chicken
Eskimo Curlew
Passenger Pigeon
Carolina Parakeet
Red-cockaded Woodpecker
Ivory-billed Woodpecker

4200 Smith School Road
Austin, Texas 78744
www.tpwd.state.tx.us

PWD BK W7000-869 (8/03)
In accordance with Texas Depository Law, this publication is available at the Texas State Publications Clearinghouse and/or Texas Depository Libraries.

TEXAS PARKS AND WILDLIFE

Migration and The Migratory Birds of Texas:

Who They Are And Where They Are Going

FOURTH EDITION

By Clifford E. Shackelford, Edward R. Rozenburg, W. Chuck Hunter and Mark W. Lockwood

Migration and The Migratory Birds of Texas: *Who They Are And Where They Are Going*

FOURTH EDITION

By Clifford E. Shackelford, Edward R. Rozenburg,
W. Chuck Hunter and Mark W. Lockwood

Cover art of migrating warblers by Rob Fleming.

Suggested Citation:
Shackelford, C. E., E. R. Rozenburg, W. C. Hunter and M. W. Lockwood. 2005. Migration and the Migratory Birds of Texas: Who They Are and Where They Are Going. Texas Parks and Wildlife PWD BK W7000-511 (11/05). Booklet, 34pp.

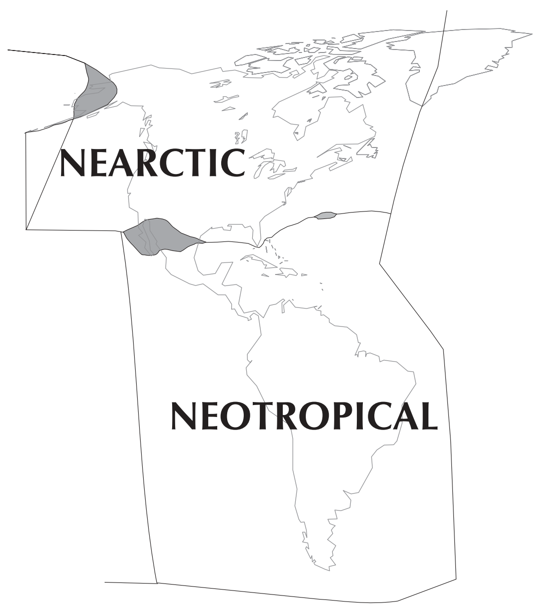
This booklet is intended to be used by the general public as an introduction to bird migration in Texas. Common names follow the 7th edition of the AOU Check-list. Added modifiers in parentheses represent distinct subspecies. All lists are in phylogenetic order.

Why is there an interest in migratory birds in Texas?

Of the 338 species that are listed as Nearctic-Neotropical migrants in North America (north of Mexico), 333 of them (or 98.5%) have been recorded in Texas. This means that of the 629 species of birds documented in Texas, 53% of them are Nearctic-Neotropical migratory birds. Texas is important to these migrants and these migrants are important to Texas.

What exactly is a Nearctic-Neotropical Migrant?

These species are collectively known by a host of other names. The species that comprise this group basically breed in temperate latitudes (i.e., U.S. and Canada), but leave for the winter for tropical latitudes farther south (i.e., Central and South America). Their migratory habits are part of their lives and heritage.



(see page 22 for world map)

TABLE OF CONTENTS

SECTION 1

Questions and Answers on Migration

What is migration?

Migration is the cyclic or periodic travel of an animal as it returns eventually to its original place of departure. Migration is often annual and is closely linked with the cyclic pattern of the seasons. It is most evident among birds, which have a highly efficient means for traveling swiftly over long distances. The migration of most birds is a yearly cycle.

Do all birds migrate?

Not all birds migrate. The more severe the climate of an area, the greater percentage of nesting birds migrate. Two-thirds of bird species found in the United States migrate, some only short distances to more southern states. Those that do migrate have adaptations not seen in their non-migratory relatives. Migratory birds can build fat stores as an energy source for long flights. Migratory birds usually have longer, more pointed wings and weigh less than related non-migratory birds.

Why do birds migrate?

There are a number of explanations for migration: (1) Birds migrate to areas where food is more abundant, (2) there is less competition for nesting space, (3) the climate is milder, or (4) the daylight hours are longer. These enhance the chances of survival of a bird and its brood. Most birds require a rich, abundant supply of food at frequent intervals because of their high metabolic rate. Adequate food is not available throughout the year in most regions. North American birds must endure the hazards of winter or migrate to more friendly climates. In winter they migrate to the warmer, southern regions of the United States, Caribbean, Mexico, Central America and South America where food is abundant. In the spring, these birds fly north to habitats where spring and summer provide more food production and less competition for food and nesting sites than in their winter habitat. Summertime at northern latitudes also means more daylight hours to seek food for themselves and their nestlings.

Where do migrating birds go?

Many nesting birds in Canada and the northern United States fly south to the tier of states along the Gulf of Mexico where the winter climate is more favorable and food is abundant. More than 330 species of birds that nest in the United States and Canada migrate to the West Indies or Central and South America. The principal wintering area for Neotropical Migrants extends through Mexico and Central America to Panama; it has the highest density of winter bird residents in the world.

Do birds follow established migratory routes?

The migratory flights of many migrating birds follow specific routes, sometimes quite well-defined, over long distances. The shape of the continent determines the main routes of migration. These routes run north to south and include the Atlantic oceanic route, the Atlantic Flyway, the Mississippi Flyway, the Central Flyway, the Pacific Flyway, and the Pacific oceanic route (see Section 2). Geographic factors, ecological conditions and meteorological conditions determine such routes. The majority of migrants travels along broad airways within these flyways changing their flight direction in response to the direction and force of the wind. Some routes cross oceans or huge bodies of water. Some small songbirds migrate 500-600 miles across the Gulf of Mexico.

How far do migrating birds travel?

Migration usually involves latitudinal or altitudinal travel. The distance may be a few miles or thousands of miles. In mountainous areas, birds, mammals and others move just a few miles from upper zones where they breed to the foothills or plains during seasons when the weather is severe and unfavorable. Clark's Nutcracker, for example, of the Rocky Mountains nests in the summer high in the mountains then winters in the lower forests.

The Ruby-throated Hummingbird nests from the southern United States up into Canada and winters as far south as Panama. Some of these little birds fly nonstop across the Gulf of Mexico (up to 600 miles). Many flycatchers fly similar routes. Some birds, such as robins or grackles, winter in large flocks in the Gulf States. The seasonal flights of American wood warblers are spectacular. Some winter in the Gulf States and the West Indies; others fly as far south as Guyana, Brazil and Peru. Tanagers and Bobolinks migrate through the eastern United States, past Cuba to southern Brazil, Bolivia, and Argentina. This area in South America is also the wintering ground for the American Golden-Plover. It leaves its nesting ground on the arctic tundra of Alaska and Canada, assembles in Labrador and southeastern Canada, then flies nonstop over the Atlantic Ocean, about 2400 miles, to Brazil. They return in the spring over Central and South America, and the Gulf of Mexico, then follow the Mississippi Valley north. The migratory champion is the Arctic Tern. It breeds in the northern most regions of Asia, Europe, and North America, then winters in the extreme southern Pacific and Atlantic Oceans at the edge of the Antarctic ice pack 11,000 miles away.

How fast do migrating birds fly?

The speed of flight depends largely on the species and the type of terrain covered. Birds fly faster when migrating than otherwise. Birds seem to fly faster in spring migration than in the fall. Migrants fly faster over water than over land. The American Golden-Plover may fly over 2400 miles south over the Atlantic Ocean at nearly 60 mph. Common Loons are among the fastest flyers at nearly 70 mph. Woodcocks on the other hand, fly at just over 10 miles per hour. Birds migrating over land may make stops for food and rest.

How high do migrating birds fly?

Most migrants fly at low altitudes, usually below 7400 feet. Small birds migrating at night fly between 800-1600 feet. In the daytime they fly much lower, often below 200 feet. Some fly much higher, the record is held by the Bar-headed Goose: 29,500 feet above sea level, over the Himalayas in India.

What birds migrate during the day?

Swift, strong fliers and hunters are often daytime, or diurnal migrants. These include pelicans, herons, birds of prey, hummingbirds, swifts, swallows and finches. Some of these birds can feed on the wing.

What birds migrate at night?

Nighttime or nocturnal migrants usually are birds that live in thick vegetation and rarely venture out of it. They include waterbirds, cuckoos, flycatchers, thrushes, warblers, orioles and buntings. Nighttime movement gives them protection from their diurnal predators. They feed and rest by day to build up energy stores for their long-distance flights at night.

Do birds usually migrate in groups?

Most birds are gregarious during migration, even those that are usually solitary at other times such as insectivores and birds of prey. Birds, such as shorebirds and waterfowl, with similar habits often migrate together. Migrating flocks will often show remarkable cohesion. Traveling in large groups provides safety for individual birds by confusing predators and making it difficult to pick out a specific victim. A characteristic migratory formation is the 'V' of geese, ducks, pelicans, and cranes with the point turned in the direction of flight.

How well can birds navigate?

Migrants often return to breed in the same locality where they were hatched. This journey may cover thousands of miles over many types of terrain and through extremes of weather. Birds show an amazing ability to orient themselves and home in on their destination. Migrating birds have many potential cues for orientation and navigation between summer and winter habitats. They do not depend on any single navigational cue.

What do birds use for orientation and navigation?

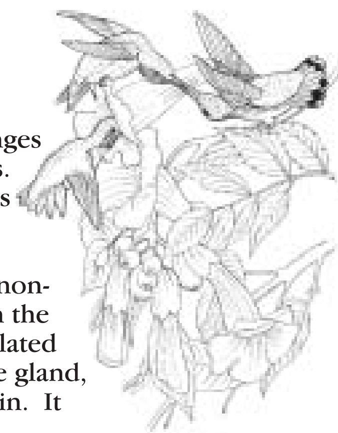
It has been demonstrated that birds use various guiding factors. These include topographic landmarks (mountains, valleys, rivers, coastlines), ecological factors (vegetation zones), and climatic changes (air masses differing in temperature and humidity). Birds have also demonstrated a compass sense. They are able to fly in a particular constant direction regardless of their starting point with respect to their destination. Birds have shown that they can relate a release point to their home area, determine which direction to take (orientation), then maintain that direction of flight (navigation). We presume this to be, in part, due to sensitivity to the intensity and direction of the earth's magnetic field. Experiments have shown that the orientation of birds is also based on celestial bearings. They can use the sun as a point of orientation during the day and the stars at night. Birds can compensate for the movement of the sun throughout the day with an internal clock mechanism that seems to give them the ability to gauge the angle of the sun above the horizon.

How do birds navigate at night?

Migrant birds that travel at night use the stars to determine their bearings. In clear weather, captive migrants head immediately in the proper direction using only the stars. They can orient themselves correctly to the arrangement of night skies projected on the dome of a planetarium. Birds apparently can determine their longitude and latitude by the position of the stars. Evidence also indicates that the glare of the moon can interfere with this orientation.

Do birds use landmarks to navigate?

Many birds, especially diurnal migrants, can recognize the topography beneath them and can navigate using familiar landmarks. Some birds follow coastlines to avoid flying over large bodies of water. At times, many follow river valleys. River valleys are like highways offering direction and shelter and food when the birds land to rest. Some birds, such as hawks, that migrate by day concentrate along mountain ranges where they ride updrafts along the mountains.



What initiates migration?

The same factors stimulate migration and reproduction. Before migration, metabolic changes occur. The thyroid gland controls these changes. Food consumption increases and fat accumulates under the skin tissues. This will provide the energy for long flights. The Ruby-throated Hummingbird stores enough fat to fly 26 hours non-stop at 25 miles an hour. This is enough to span the Gulf of Mexico. Variations in metabolism and related phenomena are controlled by another endocrine gland, the pituitary, located in the lower part of the brain. It sends out instructions by way of hormones.

What external factors prepare birds to migrate?

The pituitary is influenced by environmental factors such as day length and the intensity of the sun. The pituitary responds to increasing day length in springtime by accelerating the development of the gonads and all other metabolic processes, including the development of the thyroid, to prepare the bird for migration.

What external factors affect time of migration?

If pituitary functions and variations in day length were the only factors, migration would occur regularly every year. Such a lack of flexibility could be catastrophic for migrants because of variations in biological and meteorological conditions. Environmental factors such as weather, arrival of spring, flowering, foliation, insect hatching and availability of food vary from year to year. The pituitary prepares the bird for migration. The proper ecological conditions are necessary to trigger it. Birds can be exhausted and emaciated by the time they reach stopping areas. They gorge themselves to replenish their fat reserves before preparing for the next leg of the flight.

Does the temperature affect migration?

Weather and temperature are very important—the first cold front of the fall usually brings with it flocks of migrating geese. Many birds follow a temperature gradient as they return to nest in the spring. Birds vary in sensitivity toward temperature and other environmental conditions. Woodcocks and snipe rely on surrounding weather conditions to initiate their spring and fall migrations. The patterns of their flight depend on temperature and barometric pressure. Other birds such as swifts, swallows and orioles are less weather dependent and the dates of their departure and arrival occur with regularity each year (i.e., the swallows at Capistrano).

How does the weather affect migration?

Weather is one of the chief external influences on migration. Cool air masses moving south in the fall can trigger migratory flight. Cool air brings high pressure, low or falling temperatures and winds moving in the direction of flight and clear skies. If the cool air meets warmer air, clouds, precipitation and fog may result. Fog, especially, causes birds to descend to the ground and cease migration. Sudden changes in the weather can be disastrous for birds. In the spring, a warm, moist mass of air (low pressure with higher or rising temperatures) moving north over the Gulf of Mexico can start a wave of migrating birds to move northward from the American Tropics or southern United States. A southward moving cold front meeting such a warm air mass can result in heavy rains and high winds. This can stop migration immediately or within 24 hours. These spring "fallouts" or "groundings" of migrants may occur when the migrating birds literally fall into sheltered areas seeking food and refuge. This can be disastrous if the migrants are forced down into the ocean drowning thousands of birds. Resumption of southerly winds and rising temperatures starts migration northward again.

How did migration originate?

The roots of the migratory habits of modern birds are believed to date back millions of years, and were tempered by environmental changes caused by the Ice Ages of the Quaternary period over the last 2,500,000 years. Migration, as is known among modern birds, probably developed gradually by stages. As the environment changed, some animals changed their habitat slightly, hardly leaving their home region. The movements of others were more erratic, moving toward more favorable places. These first stages of migration were stabilized by natural selection. As winters grew more severe, much of a given bird population probably perished rather than attempting to flee any unfavorable conditions. A fraction of this population probably sought more favorable conditions elsewhere. Natural selection favored the 'migrants' and migratory tendencies were retained.

Why do birds fly to specific locations in the spring and fall?

In some cases, the original habitats were in present-day southern wintering areas. The birds developed a tendency to leave in spring to breed in territories to the north that were less crowded. Fall brought seasonal changes in weather and declining food supply in these newly settled regions. This forced the birds to migrate back to their former range for the winter. North American birds that originated in the tropics include hummingbirds, tyrant flycatchers, tanagers, wood warblers, orioles, and swifts. In recent geological times these birds gradually spread northward as glacial ice receded and the continent became warmer. Other birds, such as plovers, ducks and geese, originally lived in what are now their northern breeding areas. Gradual climatic changes forced them to spend winters far to the south. Migrations appear to be the consequences of invasions or emigrations during which animals settle in new regions during part of the annual cycle, then return to the original region to complete the cycle. Migration patterns are not fixed. As climates change, migration routes change as well, causing birds to lengthen or shorten the routes, or to abandon them altogether.

Are there any ecological implications with migration?

There are many ecological implications of migration. The sequence of migratory movement is closely integrated with the annual cycle of ecosystems that are characterized by productivity fluctuations. The food resources of some regions could not be adequately exploited without bird populations moving. Migratory behavior occurs in species located at specific trophic levels where maximum fluctuation in food production occurs in both breeding and wintering regions. Many migrant birds avoid primary equatorial forests where productivity is usually constant throughout the year and food surpluses do not occur. They do, however, congregate in savannas where productivity varies with the seasons.

How is migration coordinated with the seasons?

A coordinated sequence is apparent in the case of birds migrating from the northern Arctic regions to tropical winter regions; both life zones show broad fluctuations in productivity. In the Arctic, vegetation and animal production are very high during the summer. Ducks and shorebirds nest there in great numbers, exploiting the food resources. As winter comes, days shorten and food becomes scarce. The waterbirds migrate to southern climates where the rainy season has caused food production to increase to optimal levels. In winter, ducks and shorebirds concentrate in the most favorable areas and remain until spring when productivity there is lowest. By then, conditions at the breeding areas are again favorable for the birds. The life cycle of these birds is closely attuned with the productivity cycles in their breeding and winter habitats. The size of populations is controlled by the capacity of both habitats to sustain them.

How do human activities affect migratory birds?

The winter habitat of the “Lesser” Snow Goose is in the southeastern quarter of Texas. Combinations of mild weather, ample winter food supply and protection on numerous wildlife refuges in its wintering range, as well as the bird's natural wariness, have led to a tripling of the snow goose population in the last decade. The summer nesting range around Hudson's Bay in Canada is being destroyed by overpopulation of geese. This may lead to a collapse of the habitat's ability to support the goose population. This can lead to a major die off and nesting failure of the geese and any associated wildlife in this area of Canada.

Forest clearing for agriculture and petroleum exploration in Mexico and Central America has decreased the winter habitat of many migrant birds. The great fires of 1998 in Mexico will have, as yet, unknown effects on migrant birds. The fires have likely decreased forest habitat even further though. Migrants that returned that fall encountered decimated habitat and likely experienced a stressful winter resulting in fewer migrants returning the next spring. No one knows for sure. On the other hand, the fires created open areas that are the varied, transitional vegetation zones that many migrants prefer as habitat.

What are some human caused hazards for migrants?

Flying at night or in fog, many birds collide with tall structures. Lighthouses and skyscrapers are notorious killers of migrants. Reflective windows can be deadly. Birds see reflections of sky or trees and fly into them. Electronic towers for radio, television, cellular phones, etc. and their supporting cables kill thousands of migrating birds during migration.

Habitat loss and degradation is a much greater problem. Habitat needed for food and shelter in winter is disappearing in Latin America. Clearing of forestland and plowing of grassland for crops destroys the diverse habitat that is necessary for many species of birds to survive. In the United States and Canada there is often not enough habitat for some species to raise their young. Where there is appropriate habitat, it may be too close to human disturbances or be too small an area. The populations of many North American bird species have decreased severely over the last 100 years.

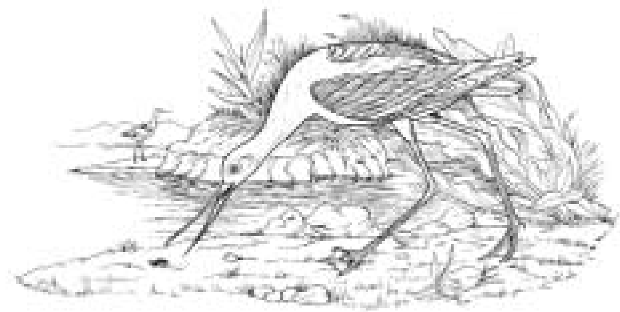
A serious man-caused hazard to migratory birds is pet cats. Free-roaming cats take a high toll on migratory birds. Scientific studies show that each year cats may kill hundreds of millions of migratory songbirds. Cats are serious threats to fledglings, birds roosting at night and birds on nests. An indoor cat is the best kind of cat.

Human introduction of exotic birds has proved detrimental to native songbirds. The European Starling, for example, is a cavity-nesting species that attacks and replaces native cavity-nesting birds which don't seem to be able to defend themselves from these aggressive invaders.

Do most migrants return after the winter?

Many birds perish during migration and the winter season. It is believed that less than half the birds that leave the nesting grounds in fall migration will return the following spring. Migration over water is one of the most hazardous times for birds, especially small songbirds. Millions of migrating birds perish at sea. These are often young birds or birds that are blown off-shore or forced down by bad weather.

Wildlife experts study waterfowl populations intensively to set hunting seasons and limits. They have a good idea of how many waterfowl head south each fall, about 100 million. About 40 million return; hunters kill about 20 million and about 40 million fall victim to predation, accidents, environmental factors and disease.



How does migration benefit birds and the environment?

Migration has considerable ecological significance. It enables fast-moving animals to exploit fluctuating resources and to settle in areas where they could not live if incapable of rapid travel. On the other hand, peaks of food production would be unexploited without the periodic presence of migratory populations.

What are migratory bird treaties?

In 1918, the United States and Great Britain (for Canada) ratified the Migratory Bird Treaty that closed hunting for certain groups of birds that migrated across their mutual borders. Hunting was permanently closed on insectivorous birds and other non-game birds. Game birds (including ducks, geese and cranes) were given protection except for an annual hunting season that could not exceed three and a half months. Additional treaties were signed with Mexico (1936), Japan (1972), and the USSR (1976) protecting migrants between the United States and those countries. These treaties protect most naturally-occuring species, while most introduced species are not protected in the U.S. (e.g.,House Sparrow, European Starling and Rock Dove [feral pigeon]).

How does migration affect the bird life of Texas?

The upper coast of Texas is in a truly unique position to observe migration. The state occurs directly in the center of the Central Flyway. Most birds that move along this route travel through Texas and eventually through the Upper Coast of Texas. Birds traveling the Atlantic Flyway during the fall reach the Florida panhandle, then may turn west and follow the Gulf Coast to Texas. Birds of the Mississippi Flyway follow that great river system to the Gulf then either cross it or turn west as well. The Pacific Flyway funnels birds between the Rocky Mountains and the Pacific Ocean. The Rockies end at Big Bend in Texas. Birds may be funneled to Big Bend where they can cross over the state and follow the Rio Grande or other watercourses to the Coast. Texas has recorded over 615 species of birds, more than any other state. These are mostly migrant birds that have followed one or more of these flyways into our state.

How are migratory birds important to man?

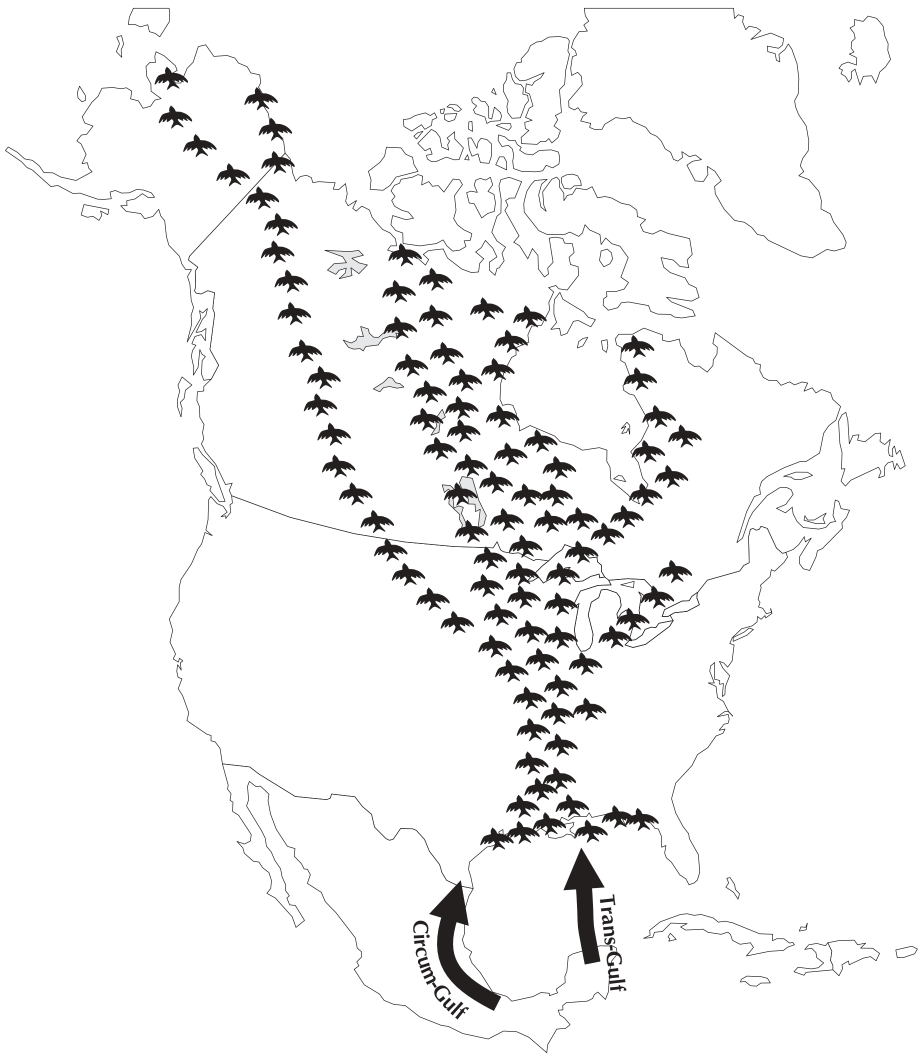
Migratory birds have considerable economic impact in North America. Since European settlers first came to the New World, they hunted various birds, such as ducks and geese, rails, doves and shorebirds, for food and sport. During the late 19th century, many species were hunted to near extinction for the market as food and feathers for adornment on women's hats. As their numbers dwindled, controls and seasons were instituted to stop their decline and stabilize the populations. Laws established to protect nongame birds and regulate hunting of game birds include the Migratory Bird Treaties mentioned above. Today, regulated hunting is a major industry in many areas of the United States. Most non-game birds were recognized to be welcome allies against insect pests. Most of the migratory birds of North America are insect eaters. Healthy, stable populations of these "songbirds" help to keep insect pests within tolerable limits. There are numerous instances where flocks of birds have descended on areas threatened with disastrous insect infestations and virtually eliminated the threat. All birds have increasing recreational value as birdwatching and other forms of nature related activities become more popular. Ecotourism, including birdwatching, camping, hiking, nature study and photography have become part of a multi-billion dollar industry. Throughout the United States, more people are engaged in nature tourism than either hunting or fishing. Together, hunting, fishing, and ecotourism are part of an industry that is worth over $100 billion annually in the United Sates alone. It pays in many ways to protect and maintain our natural assets.

SECTION 2

The Migratory Flyways of North America

Central Flyway

Mississippi Flyway



Atlantic Flyway

Pacific Flyway

SECTION 3

Timing of Selected Spring Migrants

These are selected examples and is in no way an inclusive list; involves most of Texas

SPECIES	APPROX. MIGRATION TIMING
Early-season Examples	
American Golden-Plover	early March to late April
Chimney Swift	late March to late April
Ruby-throated Hummingbird	late March to mid May
Purple Martin	mid February to early March
Barn Swallow	early March to early April
Northern Parula	early March to mid April
Black-throated Green Warbler	late March to early May
Yellow-throated Warbler	early March to mid April
Black-and-white Warbler	early March to late April
Mid-season Examples	
Hudsonian Godwit	mid April to the beginning of May
Buff-breasted Sandpiper	mid April to the beginning of May
Yellow-billed Cuckoo	mid April to mid May
Golden-winged Warbler	mid April to the beginning of May
Cerulean Warbler	mid April to the beginning of May
Late-season Examples	
Olive-sided Flycatcher	early to late May
Eastern Wood-Pewee	late April to mid May
"Traill's" Flycatcher (Alder/Willow)	early to late May
Magnolia Warbler	late April to mid May
Blackburnian Warbler	late April to mid May
Bay-breasted Warbler	late April to mid May

Further Reading on Bird Migration

This is in no way considered an inclusive list

Able, K. P. and S. A. Gauthreaux, Jr. 1975. Quantification of nocturnal passerine migration with a portable ceilometer. Condor 77:92-96.

Able, Kenneth P. 1999. Gathering of Angels: Migrating Birds and Their Ecology. Cornell Univ. Press. 193 pp.

DeGraaf, Richard M. and John H. Rappole. 1995. Neotropical Migratory Birds: Natural History, Distribution, and Population Change. Cornell Univ. Press. 676 pp.

Ehrlich, P. R., D. S. Dobkin and D. Wheye. 1988. The birder's handbook. Fireside books, New York, NY. 785 pp.

Elphick, Jonathan (editor). 1995. The Atlas of Bird Migration: Tracing the Journeys of the World's Birds. Random House Publ. 180 pp.

Finch, D. M. and P. W. Stangel. 1992. Status and management of Neotropical migratory birds. USDA Forest Service, General Technical Report RM-229. 422 pp.

Fisher, A. C. 1979. Mysteries of bird migration. National Geographic Magazine, August, pp. 154-193.

Gauthreaux, Jr., S. A. 1996. Historical perspectives in bird migration: methodologies and major research trajectories (1945-1995). Condor 98:442-453.

Gauthreaux, Jr., S. A. 1979. Priorities in bird migration studies. Auk 96:813-815.

Gauthreaux, Jr., S. A. 1972. Behavioral responses of migrating birds to daylight and darkness: a radar and direct visual study. Wilson Bulletin 84:136-148.

Gill, F. B. 1990. Ornithology. W.H. Freeman, New York, NY. 660 pp.

Greenberg, Russell and Jamie Reaser. 1995. Bring Back the Birds: What you can do to save threatened species. Stackpole Books. 312 pp.

Hagan, J. M. and D. W. Johnston. 1992. Ecology and conservation of Neotropical migrant landbirds. Smithsonian Press, Washington, DC. 609 pp.

Hamel, P. 1992. Land Manager's Guide to the birds of the south. The Nature Conservancy, Chapel Hill, NC and The U. S. Forest Service, Southern Region, Atlanta, GA. 367 pp.

Kerlinger, P. 1995. How birds migrate. Stackpole Press. 228 pp.

Kerlinger, P. and S. A. Gauthreaux, Jr. 1985. Seasonal timing, geographic distribution, and flight behavior of Broad-winged Hawks during spring migration in south Texas: a radar and visual study. Auk 102:735-743.

Lincoln, F. C. 1979. Migration of birds (revised edition) USFWS Circ. No. 16, Washington, D.C. 120 pp. (revised again in 1998 by J. L. Zimmerman)

Moore, Frank R. (editor). 2000. Stopover Ecology and Nearctic-Neotropical Landbird Migrants. Cooper Ornith. Soc., Studies in Avian Biology 20. 133 pp.

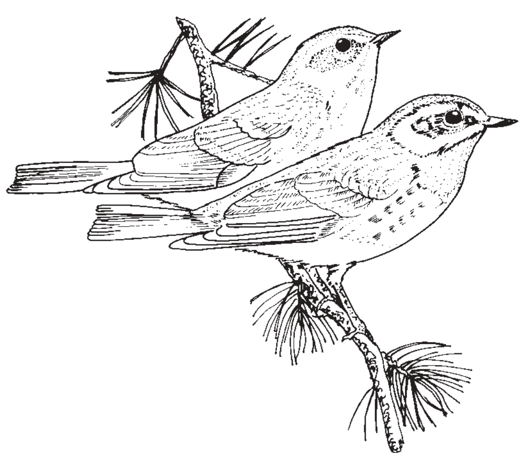
Pettingill, O. S. 1970. Ornithology in Laboratory and Field. Burgess Publ. Co., Minneapolis, MN. 524 pp.

Rappole, J. H. 1995. The ecology of migrant birds: A Neotropical perspective. Smithsonian Press. 269 pp.

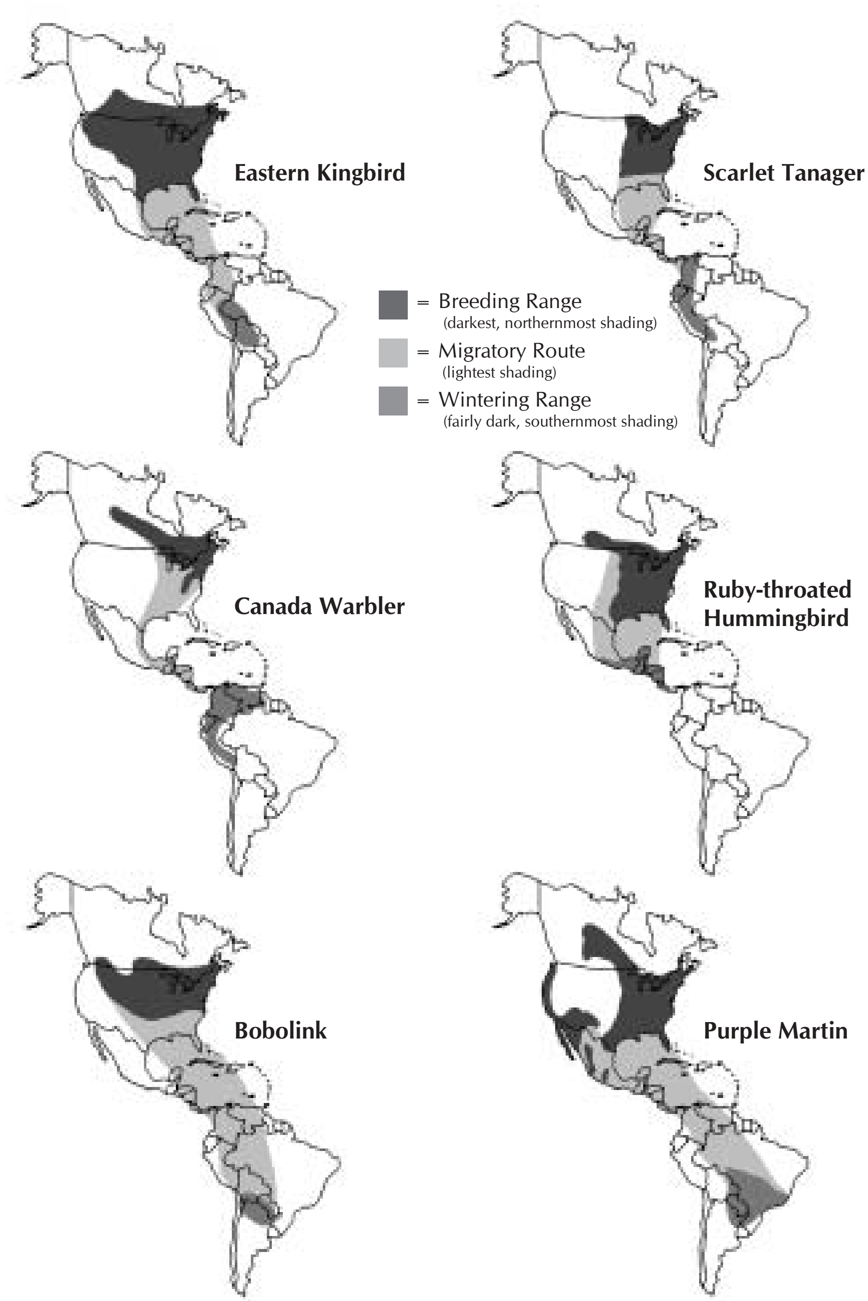
Stokes, D. and L. Stokes. 1989. A guide to bird behavior. Vol. III. Little, Brown and Co., Boston, MA. 397 pp.

Terres, J. K. 1980. Audubon Society Encyclopedia of North American birds. Alfred A. Knopf Publishing, New York, NY. 1,110 pp.

Weidensaul, Scott. 2000. Living on the Wind: Across the Hemisphere with Migratory Birds. North Point Press. 420 pp.



Migratory Routes of Selected Species: Many birds spend a lot of their lives "on the road."



SECTION 6

Grouping North American Birds by Migratory Status

Partners in Flight originally was formed to emphasize conservation of species not otherwise covered by existing conservation initiatives. Nearctic-Neotropical migratory landbirds were not included in previously existing initiatives covering waterfowl (North American Waterfowl Management Plan), shorebirds (Western Hemispheric Shorebird Reserve Network), colonial waterbirds (Colonial Waterbird Group), or for that matter numerous initiatives that focused on tropical biodiversity. However, the momentum generated under the Partners in Flight banner interestingly has led not to competing with other bird conservation initiatives, but instead to a spreading desire to link many of these initiatives together so as to pool limited resources towards shared goals and objectives (e.g., Mississippi Alluvial Plain and Prairie Pothole Migratory Bird initiatives; Mueller, et al. *in press*).

While Partners in Flight still concentrates on Nearctic-Neotropical migratory landbird conservation, planning and implementation of specific actions requires taking into account the status and potential effects of these actions on all landbirds, in both temperate and tropical areas. Although many Neotropical migrants require attention throughout the Western Hemisphere, significant concern also exists for some temperate migrants (those species remaining primarily north of the tropics) and resident species that co-occur with Neotropical migrants in both breeding and wintering habitats (Hunter 1995). In fact, Neotropical migrants provide the common link by which cooperation in conservation should occur across States and Nations, without taking anything away from conservation of highly endangered and narrowly distributed resident species, especially in the tropics.

Despite these advances in bird conservation thinking, there continues to be dissatisfaction about how to best categorize groups of migratory birds (i.e., which species are Neotropical migrants; Finch and Martin 1991). As DeGraaf and Rappole (1995), Greenberg and Reaser (1995), and other investigators correctly point out, many species of shorebirds, waterfowl, and wading birds also migrate to and from temperate breeding areas through tropical zones. These and other investigators also correctly point out that there are many tropical species migrating solely within the tropics and other species referred to as Austral migrants that breed in temperate South American habitats while wintering north into tropical zones (e.g., Chesser 1994, Nocedal 1994).

Understanding migration patterns and the underlying causes of why and where birds migrate are of course topics for serious debate, as is the expansion of what species should be included in lists of Neotropical migrants. As important as these topics are for academic debate, they add little to furthering bird conservation by themselves, especially in communicating what is important for local landowners and land managers to understand who control at least in part the fate of many vulnerable species. Obviously, species requiring conservation attention have been understood for many years to include Neotropical migrant (including species breeding in Nearctic, Neotropical, and Austral zones of the Western Hemisphere), temperate migrant, and resident (both temperate and tropical) landbirds and waterbirds (e.g., Terborgh 1989).

LITERATURE CITED

Chesser, R. T. 1994. Migration in South America: an overview of the austral system. Bird Conservation International 4:91-107.

DeGraaf, R. M., and J. H. Rappole. 1995. Neotropical migratory birds: natural history, distribution, and population change. Cornell University Press. Ithaca, New York. 676 pages.

Finch, D. M., and T. Martin. 1991. Research working group of the Neotropical migratory bird program: workplans and reports, 18 October 1991. U.S. Dept. Agric., Forest Serv., Rocky Mountain Forest and Range Exp. Sta., Laramie, Wyoming.

Greenberg, R., and J. Reaser. 1995. Bring back the birds: what you can do to save threatened species. Stackpole Books. Mechanicsburg, Pennsylvania. 312 pages.

Hunter, W. C. 1995. How much management emphasis should Neotropical migrants receive in the Southeast? 1993 Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 47:428-438.

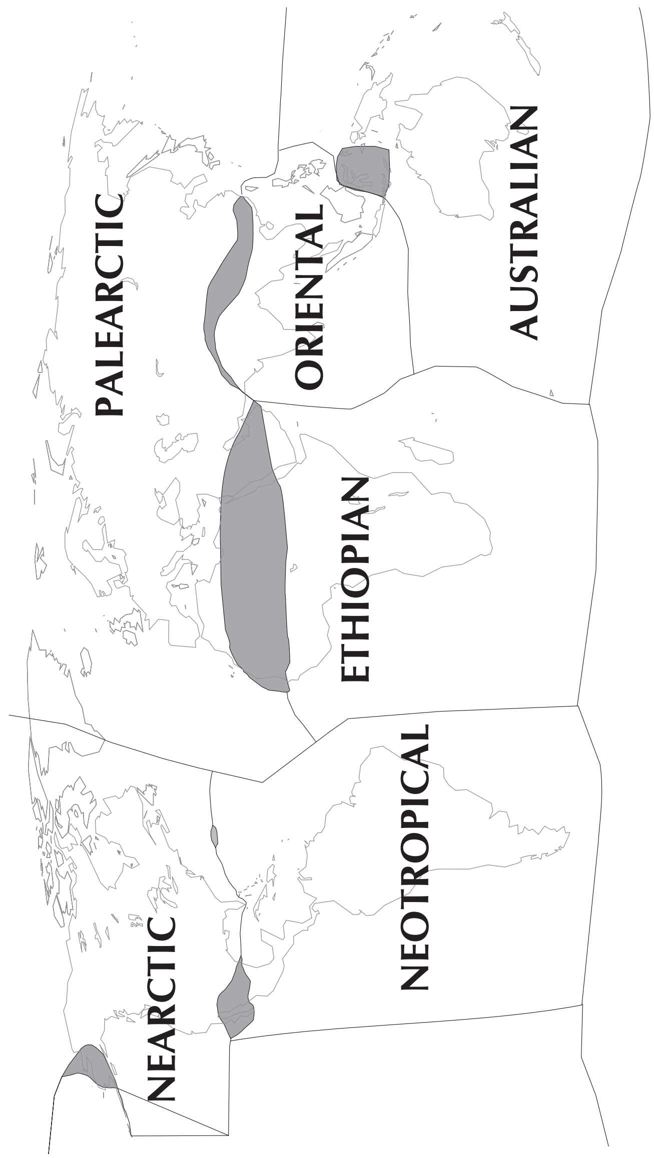
Mueller, A. J., C. R. Loesch, and D. J. Twedt. *in press*. Development of management objectives for breeding birds in Mississippi Alluvial Valley. In press. Proc. of the 1995 Partners in Flight International Workshop, October 1-5, 1995, The Cape May, New Jersey.

Nocedal, J. 1994. Local migrations of insectivorous birds in western Mexico: implications for the protection and conservation of their habitats. Bird Conservation International 4:129-142.

Terborgh, J. 1989. Where have all the birds gone. Princeton University Press, Princeton, New Jersey. 207 pages.

The Migratory Birds of Texas

ZOOGEOGRAPHIC REGIONS OF THE WORLD
(not including Antarctica)



Pantropical = **Southern latitudes excluding Australia and Antarctica; tropical regions of Neotropical + Ethiopian + Oriental**

Holarctic = **Northern latitudes; Nearctic + Palearctic**

Shaded Areas are regions of overlap

I. NEARCTIC-NEOTROPICAL MIGRANTS

1. Breeding: Temperate; Wintering: Middle America

a. Landbirds
Band-tailed Pigeon
Flammulated Owl
Lesser Nighthawk
Whip-poor-will
Ruby-throated Hummingbird
Black-chinned Hummingbird
Calliope Hummingbird
Broad-tailed Hummingbird
Rufous Hummingbird
(Allen's Hummingbird)
Yellow-bellied Flycatcher
Willow Flycatcher
Least Flycatcher
Hammond's Flycatcher
Dusky Flycatcher
Cordilleran Flycatcher
Ash-throated Flycatcher
Cassin's Kingbird
Western Kingbird
Scissor-tailed Flycatcher
Violet-green Swallow
Northern Rough-winged Swallow
Cave Swallow
House Wren
Wood Thrush
Bell's Vireo
Black-capped Vireo *
Blue-headed Vireo
Cassin's Vireo
Plumbeous Vireo
Warbling Vireo
Blue-winged Warbler
Orange-crowned Warbler
Nashville Warbler
Virginia's Warbler
Colima Warbler
Lucy's Warbler
Chestnut-sided Warbler
Black-throated Gray Warbler
Townsend's Warbler
Hermit Warbler
Golden-cheeked Warbler *
Kentucky Warbler
MacGillivray's Warbler
Wilson's Warbler
(Red-faced Warbler)
Yellow-breasted Chat
Western Tanager
Black-headed Grosbeak
Blue Grosbeak
Lazuli Bunting
"Texas" Painted Bunting
Chipping Sparrow
Lincoln's Sparrow
Hooded Oriole
Bullock's Oriole
Scott's Oriole

b. Waterbirds
Anhinga
White-faced Ibis
Wood Stork
Blue-winged Teal
Cinnamon Teal
Common Moorhen

2. Breeding: Temperate; Wintering: Middle America and West Indies

a. Landbirds
Cave Swallow
Blue-gray Gnatcatcher
Gray Catbird
White-eyed Vireo
Northern Parula
Magnolia Warbler
Black-throated Green Warbler
Yellow-throated Warbler
Palm Warbler
Worm-eating Warbler
Swainson's Warbler
Ovenbird
Hooded Warbler
Indigo Bunting
"Western" Grasshopper Sparrow

2. Breeding: Temperate; Wintering: Middle America and West Indies *(continued)*

b. Waterbirds

Least Bittern
Green Heron
White Ibis
Forster's Tern

3. Breeding Landbirds: Temperate; Wintering: Middle America and South America

Broad-winged Hawk
Olive-sided Flycatcher
Acadian Flycatcher
Great Crested Flycatcher
Barn Swallow
Swainson's Thrush
Philadelphia Vireo
Golden-winged Warbler
Tennessee Warbler
Yellow Warbler
Bay-breasted Warbler
Mourning Warbler
Summer Tanager
Rose-breasted Grosbeak
Dickcissel
Orchard Oriole

4. Breeding: Temperate and/or Tropical; Wintering: South Florida and/or West Indies

(Short-tailed Hawk)
(Mangrove Cuckoo)
(Gray Kingbird)
Cape May Warbler
Black-throated Blue Warbler
Prairie Warbler
"Eastern" Painted Bunting
(Shiny Cowbird)

5. Breeding: Temperate and/or Tropical; Wintering: South America

a. Landbirds

Swallow-tailed Kite
Mississippi Kite
Swainson's Hawk
Black-billed Cuckoo
Yellow-billed Cuckoo
Common Nighthawk
Chimney Swift
Western Wood-Pewee
Eastern Wood-Pewee
Alder Flycatcher
(Sulphur-bellied Flycatcher)
Eastern Kingbird
Purple Martin
Bank Swallow
Cliff Swallow
Veery
Gray-cheeked Thrush
Red-eyed Vireo
(Yellow-green Vireo)
(Black-whiskered Vireo)
Blackburnian Warbler
Blackpoll Warbler
Cerulean Warbler
(Connecticut Warbler)
Canada Warbler
Scarlet Tanager
Bobolink

5. Breeding: Temperate and/or Tropical; Wintering: South America

b. Waterbirds

American Golden-Plover
Solitary Sandpiper
Upland Sandpiper
Eskimo Curlew *
Hudsonian Godwit
Red Knot
White-rumped Sandpiper
Baird's Sandpiper
Pectoral Sandpiper
Stilt Sandpiper
Buff-breasted Sandpiper
Wilson's Phalarope
Red-necked Phalarope
(Red Phalarope)
Pomarine Jaeger
Parasitic Jaeger
(Long-tailed Jaeger)
Franklin's Gull
Sabine's Gull
(Arctic Tern)
"Interior" Least Tern *
Black Tern

6. Breeding: Temperate; Wintering: Middle and South America and West Indies

a. Landbirds

Osprey
Merlin
"Arctic" Peregrine Falcon *
Chuck-will's-widow
Yellow-throated Vireo
Black-and-white Warbler
American Redstart
Prothonotary Warbler
Northern Waterthrush
Louisiana Waterthrush
Common Yellowthroat
Baltimore Oriole

b. Waterbirds

Brown Pelican *
Great Egret
Snowy Egret
Little Blue Heron
Tricolored Heron
Reddish Egret
Cattle Egret
Black-crowned Night-Heron
Yellow-crowned Night-Heron
Roseate Spoonbill
Wood Stork
Purple Gallinule
Black-bellied Plover
Wilson's Plover
Semipalmated Plover
Black-necked Stilt
Greater Yellowlegs
Lesser Yellowlegs
Spotted Sandpiper
Whimbrel
Ruddy Turnstone
Sanderling
Semipalmated Sandpiper
Western Sandpiper
Least Sandpiper
Short-billed Dowitcher
Laughing Gull
Gull-billed Tern
Caspian Tern
Royal Tern
Sandwich Tern
Common Tern
Black Skimmer

7. Breeding Landbirds: Southwest U.S. and Mexico; Wintering: further south into Middle America

(Common Black-Hawk)
Gray Hawk
Zone-tailed Hawk
Aplomado Falcon *
Red-billed Pigeon
White-winged Dove
Groove-billed Ani
Elf Owl
Whip-poor-will
(Broad-billed Hummingbird)
(White-eared Hummingbird)
(Berylline Hummingbird)
Buff-bellied Hummingbird
(Violet-crowned Hummingbird)
Blue-throated Hummingbird
Magnificent Hummingbird
Lucifer Hummingbird
(Elegant Trogon)
Northern Beardless-Tyrannulet

II. INTRA-NEOTROPICAL MIGRANTS

(most movements within tropical zones, but occasionally disperses northward into the southern U.S.)

a. Landbirds
(Ruddy Ground-Dove)
(Tamaulipas Crow)
(Clay-colored Robin)
(Rufous-backed Robin)
(Rufous-capped Warbler)
(Flame-colored Tanager)

b. Waterbirds
(Blue-footed Booby)
Magnificent Frigatebird
("Great White" Heron)
Fulvous Whistling-Duck
Black-bellied Whistling-Duck
(Masked Duck)
(Northern Jacana)

III. NEARCTIC-TEMPERATE MIGRANTS

1. Breeding: Temperate; Wintering: southern North Temperate and northern Neotropics (major shifts between breeding and non-breeding distributions)

a. Landbirds
Northern Harrier
Sharp-shinned Hawk
Cooper's Hawk
Long-eared Owl
Short-eared Owl
Belted Kingfisher
Yellow-bellied Sapsucker
Red-naped Sapsucker
Williamson's Sapsucker
Eastern Phoebe
Say's Phoebe
Tree Swallow
Brown Creeper
Sedge Wren
Marsh Wren
Golden-crowned Kinglet
Ruby-crowned Kinglet
Townsend's Solitaire
Hermit Thrush
American Pipit
Cedar Waxwing
Yellow-rumped Warbler
Vesper Sparrow
Savannah Sparrow
Swamp Sparrow
White-crowned Sparrow
Western Meadowlark
Brewer's Blackbird
Cassin's Finch
Pine Siskin
(Evening Grosbeak)

1. Breeding: Temperate; Wintering: southern North Temperate and northern Neotropics (major shifts between breeding and non-breeding distributions) *(continued)*

b. Waterbirds

Pied-billed Grebe
Eared Grebe
Western Grebe
Clark's Grebe
American White Pelican
American Bittern
Great Blue Heron
Green-winged Teal
Northern Pintail
Northern Shoveler
Gadwall
American Wigeon
Canvasback
Redhead
Ring-necked Duck
Lesser Scaup
Bufflehead
Ruddy Duck
Black Rail
Virginia Rail
Sora
Snowy Plover
Piping Plover *
American Avocet
Willet
Marbled Godwit
(Surfbird)
Long-billed Dowitcher
Common Snipe
Ring-billed Gull
(California Gull)
Herring Gull

2. Breeding: Temperate; Wintering: southern North Temperate and northern Neotropics (minor shift between breeding and non-breeding distributions)

a. Landbirds

Turkey Vulture
(Northern Goshawk)
Red-tailed Hawk
"Northern" American Kestrel
Mourning Dove
Burrowing Owl
(Northern Saw-whet Owl)
White-throated Swift
"Red-shafted" Northern Flicker
Black Phoebe
Horned Lark
Chihuahuan Raven
Rock Wren
Bewick's Wren
Eastern Bluebird
Western Bluebird
American Robin
Northern Mockingbird
Loggerhead Shrike
Pine Warbler
Spotted Towhee
Red-winged Blackbird
Eastern Meadowlark
Brown-headed Cowbird
House Finch
Red Crossbill (all types)
Lesser Goldfinch

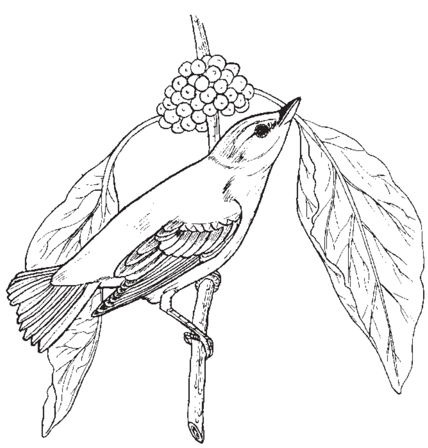
b. Waterbirds

Mallard
American Coot
Killdeer

3. Breeding and wintering: Temperate (can include northern Mexico; major shifts between breeding and non-breeding distributions)

a. Landbirds

Bald Eagle
"Harlan's" Red-tailed Hawk
Rough-legged Hawk
Golden Eagle
(Lewis' Woodpecker)
(Red-breasted Sapsucker)
Red-breasted Nuthatch
Winter Wren
(Varied Thrush)
(Bohemian Waxwing)
(Northern Shrike)
American Tree Sparrow
Henslow's Sparrow
Le Conte's Sparrow
Nelson's Sharp-tailed Sparrow
Fox Sparrow
Song Sparrow
White-throated Sparrow
(Golden-crowned Sparrow)
Harris' Sparrow
Dark-eyed Junco
Lapland Longspur
Smith's Longspur
(Snow Bunting)
Rusty Blackbird
Purple Finch
(Common Redpoll)
American Goldfinch



b. Waterbirds

(Red-throated Loon)
(Pacific Loon)
Common Loon
(Yellow-billed Loon)
Horned Grebe
(Red-necked Grebe)
Northern Gannet
Double-crested Cormorant
(Tundra Swan)
(Trumpeter Swan)
Greater White-fronted Goose
Snow Goose
Ross's Goose
(Brant)
Canada Goose
(American Black Duck)
Greater Scaup
(King Eider)
(Harlequin Duck)
(Oldsquaw)
(Black Scoter)
Surf Scoter
White-winged Scoter
Common Goldeneye
(Barrow's Goldeneye)
Hooded Merganser
Common Merganser
Red-breasted Merganser
Yellow Rail
King Rail
Whooping Crane *
(Purple Sandpiper)
Dunlin
Bonaparte's Gull
(Mew Gull)
(Thayer's Gull)
(Iceland Gull)
(Western Gull)
(Glaucous Gull)
(Black-legged Kittiwake)

4. Breeding: Temperate; Wintering: Southwest U.S. and Northern Mexico (arid temperate)

a. Landbirds
Ferruginous Hawk
Prairie Falcon
Common Poorwill
Anna's Hummingbird
(Costa's Hummingbird)
Gray Flycatcher
Mountain Bluebird
Sage Thrasher
Sprague's Pipit
Phainopepla
Gray Vireo
Green-tailed Towhee
Cassin's Sparrow
Clay-colored Sparrow
Brewer's Sparrow
Black-chinned Sparrow
Lark Sparrow
Black-throated Sparrow
Sage Sparrow
Lark Bunting
(Baird's Sparrow)
McCown's Longspur
Chestnut-collared Longspur
Yellow-headed Blackbird
(Lawrence's Goldfinch)

b. Waterbirds
Sandhill Crane
Mountain Plover
Long-billed Curlew

5. Breeding and wintering: Temperate (including northern Mexico; minor shift between breeding and non-breeding distributions)

a. Landbirds
Red-shouldered Hawk
(Snowy Owl)
Red-headed Woodpecker
"Yellow-shafted" Northern Flicker
Blue Jay
American Crow
Fish Crow
Brown Thrasher
Eastern Towhee
Bachman's Sparrow
Field Sparrow
Seaside Sparrow
Common Grackle
(Pine Grosbeak)
(White-winged Crossbill)

b. Waterbirds
Glossy Ibis
Wood Duck
American Woodcock
(Great Black-backed Gull)

IV. NEARCTIC-PALEARCTIC/ PANTROPICAL MIGRANTS

1. Breeding Waterbirds: Arctic/Alaska; Wintering: Tropical Pacific Islands

(Wandering Tattler)

2. Breeding Landbirds: Arctic/Alaska; Wintering: Eastern Hemisphere and/or Alaska away from breeding sites

(Northern Wheatear)

3. Breeding Waterbirds: West Indies; Non-breeding: Disperses northward

(Black-capped Petrel)
(Audubon's Shearwater)

4. Breeding Waterbirds: Southern Hemisphere; Non-breeding: Disperses northward

(Greater Shearwater)
(Sooty Shearwater)
(Wilson's Storm-Petrel)

5. Breeding Waterbirds: Eurasia (Eastern Atlantic); Non-breeding: Disperses west and east

(Cory's Shearwater)
(Manx Shearwater)
(Eurasian Wigeon)
(Little Gull)
(Black-headed Gull)
(Lesser Black-backed Gull)

6. Breeding Waterbirds: Pantropical; Non-breeding: Disperses northward

(Audubon's Shearwater)
(Band-rumped Storm-Petrel)
(Red-billed Tropicbird)
(Masked Booby)
(Brown Booby)
(Red-footed Booby)
(Roseate Tern)
(Bridled Tern)
(Sooty Tern)
(Brown Noddy)
(Black Noddy)

7. Breeding Waterbirds: Gulf of California; Non-breeding: Disperses northward

(Heerman's Gull)
(Yellow-footed Gull)
(Elegant Tern)

8. Resident species in both Nearctic and Neotropical Zoogeographic Regions ("resident" includes species with movements within their breeding range)

a. Landbirds
Black Vulture
Wild Turkey
Northern Bobwhite
Barn Owl
Eastern Screech-Owl
Western Screech-Owl
Great Horned Owl
(Northern Pygmy-Owl)
(Spotted Owl)
Barred Owl
Acorn Woodpecker
Hairy Woodpecker
Western Scrub-Jay
Steller's Jay
Common Raven
Tufted Titmouse
Bushtit
White-breasted Nuthatch
Pygmy Nuthatch
Canyon Wren
Carolina Wren
(American Dipper)
Hutton's Vireo
Northern Cardinal
Great-tailed Grackle

b. Waterbirds
Mottled Duck
Clapper Rail
American Oystercatcher

9. Resident species or subspecies found primarily within Nearctic Zoogeographic Region

"Southeastern" American Kestrel
"Attwater's" Greater Prairie-Chicken *
Lesser Prairie-Chicken
Red-bellied Woodpecker
Downy Woodpecker
Red-cockaded Woodpecker *
Pileated Woodpecker
(Pinyon Jay)
(Clark's Nutcracker)
(Black-billed Magpie)
(Black-capped Chickadee)
Carolina Chickadee
Mountain Chickadee
Juniper Titmouse
Brown-headed Nuthatch
Boat-tailed Grackle

10. Resident species within southern North Temperate and Neotropical Zoogeographic Region

a. Landbirds

Hook-billed Kite
White-tailed Kite
(Snail Kite)
"Northern" Sharp-shinned Hawk
Harris's Hawk
Broad-winged Hawk†
(Short-tailed Hawk)
White-tailed Hawk
Crested Caracara
Plain Chachalaca
Montezuma Quail
Inca Dove
Common Ground-Dove
White-tipped Dove
(Mangrove Cuckoo)
Ferruginous Pygmy-Owl
Common Pauraque
Ringed Kingfisher
Green Kingfisher
Golden-fronted Woodpecker
Ladder-backed Woodpecker
Great Kiskadee
Green Jay
Brown Jay
Mexican Jay
Long-billed Thrasher
Olive Sparrow
White-collared Seedeater
(Yellow-eyed Junco)
Altamira Oriole
Audubon's Oriole

b. Waterbirds

Least Grebe
Neotropic Cormorant

† not nesting in tropics

11. Resident landbird species centered in Southwest U.S. and Northern Mexico

Scaled Quail
Gambel's Quail
Greater Roadrunner
Verdin
Cactus Wren
Black-tailed Gnatcatcher
Curve-billed Thrasher
Crissal Thrasher
Pyrrhuloxia
Canyon Towhee
Rufous-crowned Sparrow

LEGEND:

* = endangered species/subspecies

(species) = species in parentheses are considered either very rare and local in Texas or as a vagrant in Texas

TRANS-GULF MIGRANTS

Defined as those bird species that cross the Gulf of Mexico from the Yucatan Peninsula to the U. S. Gulf Coast (Texas to Florida). Trans-Gulf migration is characteristic of the following species, but does not exclude the possibility of some circum-Gulf passage either. Bird migration is not black or white. In the biological world there are rules, but there are always exceptions. This is not a complete list.

Chimney Swift
Ruby-throated Hummingbird
Belted Kingfisher
Yellow-bellied Sapsucker
Black-billed Cuckoo
Yellow-billed Cuckoo
Common Nighthawk
Chuck-will's-widow
Whip-poor-will
Olive-sided Flycatcher
Eastern Wood-Pewee
Eastern Phoebe
Great Crested Flycatcher
Eastern Kingbird
Western Kingbird
Scissor-tailed Flycatcher
White-eyed Vireo
Blue-headed Vireo
Yellow-throated Vireo
Warbling Vireo
Philadelphia Vireo
Red-eyed Vireo
Purple Martin
Barn Swallow
Cliff Swallow
House Wren
Marsh Wren
Veery
Gray-cheeked Thrush
Swainson's Thrush
Hermit Thrush
Wood Thrush
Gray Catbird
Cedar Waxwing
Blue-winged Warbler
Golden-winged Warbler
Tennessee Warbler
Nashville Warbler
Northern Parula
Yellow Warbler
Chestnut-sided Warbler
Magnolia Warbler
Cape May Warbler
Black-throated Blue Warbler
Yellow-rumped Warbler
Black-throated Green Warbler
Blackburnian Warbler
Yellow-throated Warbler
Prairie Warbler
Palm Warbler
Bay-breasted Warbler
Blackpoll Warbler
Cerulean Warbler
Black-and-white Warbler
American Redstart
Prothonotary Warbler
Worm-eating Warbler
Swainson's Warbler
Ovenbird
Northern Waterthrush
Louisiana Waterthrush
Kentucky Warbler
Common Yellowthroat
Hooded Warbler
Yellow-breasted Chat
Summer Tanager
Scarlet Tanager
Rose-breasted Grosbeak
Blue Grosbeak
Dickcissel
Bobolink
Orchard Oriole
Baltimore Oriole

SECTION 8

CIRCUM-GULF MIGRANTS

Defined as those bird species that generally migrate by “hugging” the coastline from Mexico through Texas in spring and the reverse in fall (usually do not cross Gulf waters). Again, bird migration is not black or white. This list is meant as a tool, not a rule. This is not a complete list.

Turkey Vulture
Swallow-tailed Kite
Mississippi Kite
Northern Harrier
Sharp-shinned Hawk
Cooper’s Hawk
Broad-winged Hawk
Yellow-bellied Flycatcher
Least Flycatcher
Tree Swallow
Bank Swallow
Ruby-crowned Kinglet
Blue-gray Gnatcatcher
American Pipit
Orange-crowned Warbler
Mourning Warbler
Wilson’s Warbler
Canada Warbler
Chipping Sparrow
Vesper Sparrow
Savannah Sparrow
Swamp Sparrow
Indigo Bunting
Painted Bunting

This Outreach Publication
is a Partnership Project Among:

Wildlife Diversity Program
and
Natural Resource Program

4200 Smith School Road
Austin, Texas 78744

PWD BK W7000-511 (11/05)

Great Trinity Forest Management Plan

Wildlife Management

Seasonal Bird Use of Canopy Gaps in a Bottomland Forest

The Wilson Journal of Ornithology 119(1):77–88, 2007

SEASONAL BIRD USE OF CANOPY GAPS IN A BOTTOMLAND FOREST

LIESSA T. BOWEN,[1] CHRISTOPHER E. MOORMAN,[1,3] AND JOHN C. KILGO[2]

ABSTRACT.—Bird use of small canopy gaps within mature forests has not been well studied, particularly across multiple seasons. We investigated seasonal differences in bird use of gap and forest habitat within a bottomland hardwood forest in the Upper Coastal Plain of South Carolina. Gaps were 0.13- to 0.5-ha, 7- to 8-year-old group-selection timber harvest openings. Our study occurred during four bird-use periods (spring migration, breeding, postbreeding, and fall migration) in 2001 and 2002. We used plot counts and mist netting to estimate bird abundance in canopy gaps and surrounding mature forest habitats. Using both survey methods, we observed more birds, including forest-interior species, forest-edge species, field-edge species, and several individual species in canopy gap and gap-edge habitats than in surrounding mature forest during all periods. Interactions between period and habitat type often were significant in models, suggesting a seasonal shift in habitat use. Bird activity generally shifted between the interior of canopy gaps and the immediate gap edge, but many species increased their use of forested habitat during the breeding period. This suggests that many species of birds selectively choose gap and gap-edge habitat over surrounding mature forest during the non-breeding period. Creation of small canopy gaps within a mature forest may increase local bird species richness. The reasons for increased bird activity in gaps remain unclear. *Received 8 August 2005. Accepted 12 July 2006.*

Many species of birds, including several species of conservation concern that breed in mature forests, require some amount of forest disturbance to create ideal habitat (Hunter et al. 2001). One type of disturbance common in mature forests occurs when trees fall from fire, ice, wind, or insect damage creating small light gaps in the forest canopy. Such gaps provide microclimates and habitat patches that lead to a unique assortment of gap-associated flora and fauna (Watt 1947, Canham et al. 1990), and increase the heterogeneity of vegetation structure in the forest. Canopy gaps created by small-scale timber harvest operations may mimic these natural disturbances.

Birds select habitat based largely upon vegetation structure (Holmes et al. 1979), and some may prefer early successional gap habitat based on the unique qualities of the vegetation (e.g., dense foliage, well-developed herb and shrub layer). Several bird species seem to prefer small-scale canopy gap openings to mature forested habitat during migration or the breeding period (Martin and Karr 1986, Germaine et al. 1997, Kilgo et al. 1999, Moorman and Guynn 2001). Forest canopy gaps may be used differently throughout the year, depending on the availability of protective cover, desirable nesting habitat, or suitable prey items (Robinson and Holmes 1982, Willson et al. 1982, Blake and Hoppes 1986). During migration, birds pass through unfamiliar habitats and tend not to spend much time in any one location (Moore et al. 1993). Habitat selection during these periods may be influenced by available food resources, competition with other species, and risk of predation (Petit 2000). During the breeding period, birds require habitat with suitable nesting sites. Birds that breed in early successional habitats, including Common Yellowthroat and Indigo Bunting (scientific names in Appendix), use regenerating canopy gaps for nesting (Moorman and Guynn 2001). During the postbreeding period, adults may select densely vegetated habitats as refugia while molting (Vega Rivera et al. 1999), and young may seek the protective cover from predators offered by gaps (Anders et al. 1998, Vega Rivera et al. 1998), as each group is particularly vulnerable at that time.

Seasonal variation in the use of artificial, small-scale disturbances by birds within mature forests has not been well studied, and no research has systematically addressed the relative use of gap habitat throughout the growing season, beginning with spring migration

[1] Department of Forestry and Environmental Resources, Campus Box 8003, North Carolina State University, Raleigh, NC 27695, USA.

[2] Southern Research Station, USDA Forest Service-Savannah River, P. O. Box 700, New Ellenton, SC 29809, USA.

[3] Corresponding author; e-mail: chris_moorman@ncsu.edu

and ending with fall migration. Our goal was to examine relative use of gap and forest habitat by birds through four periods (spring, breeding, postbreeding, and fall) within a bottomland hardwood forest to provide a more comprehensive assessment of the response of forest birds to canopy gaps. We hypothesized that relative bird use of gaps would be highest during the non-breeding period when dense vegetative cover is important to dispersing and migrating individuals.

METHODS

Study Area.—We studied birds during 2001 and 2002 at the Savannah River Site (33° 09′ N, 81° 40′ W), a 78,000-ha National Environmental Research Park owned and operated by the U.S. Department of Energy. Our study site was a mature stand of bottomland hardwoods approximately 120 ha in size in Barnwell County in the Upper Coastal Plain of South Carolina. We surveyed birds in 12 group-selection gaps harvested in December 1994 and in the mature forest adjacent to gaps. Gaps were of three sizes (0.13, 0.26, and 0.50 ha) with four replicates of each size. It is within this size range that previous research has identified a threshold in response by breeding (Moorman and Guynn 2001) and fall migrant birds (Kilgo et al. 1999). The mature forest canopy was dominated by laurel oak (*Quercus laurifolia*), cherrybark oak (*Q. falcata* var. *pagodaefolia*), sweetgum (*Liquidambar styraciflua*), and loblolly pine (*Pinus taeda*). The midstory was poorly developed, consisting primarily of red mulberry (*Morus rubra*), ironwood (*Carpinus carolinianus*), and American holly (*Ilex opaca*). The understory was dominated by dwarf palmetto (*Sabal minor*) and switchcane (*Arundinaria gigantea*). Vegetation in the gaps was approximately 1–8 m in height and was dominated by regenerating trees (primarily sweetgum, loblolly pine, sycamore [*Platanus occidentalis*], green ash [*Fraxinus pennsylvanica*], oaks, and black willow [*Salix nigra*]), and dense stands of blackberry (*Rubus* spp.), dwarf palmetto, and switchcane.

Bird Surveys.—We surveyed birds each year during four avian activity periods: spring migration (25 Mar through 15 May), breeding (16 May through 30 Jun), postbreeding (1 Jul through 31 Aug), and fall migration (1 Sep through 18 Oct). These beginning and ending dates are estimates of biologically meaningful periods, but each overlaps extensively with the other. Although many individuals initiated breeding on our study area before 16 May, transient species that breed to the north continued to migrate through South Carolina until mid-May. Similarly, some individuals migrated from or through our study area before 1 September, but the bulk of fall migration occurred after 1 September.

Plot counts were conducted within each of the 12 experimental gaps and within 12 forested control plots of equivalent size. The 12 forested control plots were randomly placed a minimum of 100 m from the nearest gap center within the mature forest surrounding the study gaps. The forest plot perimeters were flagged so that observers could easily identify plot boundaries. Each of the 24 plots was visited three times during each period and counts were averaged over the three visits. For approximately one half of the plot counts and equally distributed across treatment types, two observers walked slowly around the perimeter of each plot, recording all birds seen and heard. When the observers met on the opposite side of the plot, they compared observations and agreed upon a total number for each bird species observed within the gap-edge habitat. When only one observer was available, the single observer walked slowly around the entire plot. At both forest and gap plots, birds observed within the actual plot and at the immediate edge (0–10 m from the bole line or flagged boundary into the forest) were included in the count. Surveys varied widely in length (15 to 45 min); larger plots and plots with more bird activity took longer to survey. The percentage of gap habitat in plot counts increased as gap size increased. However, the effect of gap size on bird use was not significant ($P > 0.05$) and we did not include the variable in our models.

At each of the 12 study gaps, we placed three constant effort mist-net stations along a line emanating southward from the gap center: one at the approximate gap center, one at the gap edge perpendicular to and bisecting the tree line, and one 50 m into the surrounding forest. The interior gap mist net was a proxy for gap abundance, the gap-edge net was a proxy for edge abundance, and the 50-m-into-the-forest net was a proxy for forest abundance. During the spring migration, post-breeding, and fall migration periods, netting was conducted once each week at each gap, rotating among gaps on a regular weekly schedule. During the breeding period, nets were operated once every 2 weeks because birds tend to remain fairly stationary during this period. Nets were opened at first light and operated for 4–6 hrs, depending on daily weather conditions. Netting was not conducted when wind exceeded 16 km/hr or during steady rainfall. Nets were 12 m long $\times$ 3 m tall, with 30-mm mesh. Captured birds were classified to age and gender (Pyle 1997), weighed, and banded with a federal aluminum leg band. We operated mist nets for a total of 7,669 net hrs over the 2 years of the study.

Mist-net surveys and plot counts were not meant to be directly comparable, but rather separate, distinct measures of bird use of gap and adjacent forest habitat in each of four bird-use periods. Plot counts at gap sites included both gap and edge habitat, so the percentage of bird use of gap *per se* versus the first 10 m of forest (i.e., the edge) could not be measured seasonally as it could for mist-net captures. We chose not to note whether birds specifically were recorded in the 10-m outer band of gap and control plot counts because birds often moved back and forth across the boundary as they foraged. Additionally, we were most interested in bird use of gap-edge habitat compared to an equal size area of mature forest. Finally, forest mist-net stations were not placed with control plot count circles because the best location (i.e., at least 100 m from the nearest gap center) for plot counts frequently did not lie along the southward emanating mist-net transect. Mist nets and plot counts each have their limitations, but the combined use of the two sampling techniques allowed us to more comprehensively measure bird use of the gaps and adjacent mature forest.

Statistical Analyses.—We used a linear mixed model (PROC MIXED, SAS Institute, Inc. 1990) to perform repeated measures ANOVA comparing the effects of habitat type, period, and the interaction between habitat and period on bird abundance. We used mean birds per ha as the dependent variable for plot count analyses and mean captures per 100 net hrs as the dependent variable for mist-netting analyses. For plot count data analysis, habitats included gap-edge and forest; for mist-netting data analysis, habitats included gap, edge, and forest. We considered habitat type and period as fixed effects, with habitat type as a split plot factor and period as the repeated measure. We used the test for the habitat $\times$ period interaction to assess whether habitat use was consistent across periods (i.e., an interaction between the two variables indicated that relative use of the habitats differed among the periods). Significant interactions generally were the result of varying extents of differences among gap, edge, and forest use but in a consistent direction across periods. We interpreted period and habitat effects separately even when there was an interaction between the two variables. Years were not significant ($P > 0.05$) in any model and were pooled in the final analyses. These pooled data are represented in tables and figures.

We assigned birds to habitat-use groups (Appendix): (1) all birds, (2) forest-interior species, (3) forest-edge species, and (4) field-edge species (Ehrlich et al. 1988, Hamel 1992). We analyzed mist-netting captures and plot count detections for each group. Individual species were chosen for analysis if they accounted for at least 80 detections over both years for plot counts (Blue-gray Gnatcatcher, Carolina Wren, Tufted Titmouse, Northern Cardinal, Northern Parula, and White-eyed Vireo) or at least 80 captures over both years for mist netting (Black-throated Blue Warbler, Carolina Wren, Hooded Warbler, Kentucky Warbler, Northern Cardinal, and White-eyed Vireo). We included species that bred at our study site and transient migrants that bred to the north in our analyses. Birds considered winter residents, present only in early spring or late fall, were not included.

RESULTS

Plot Counts.—From April through October in 2001 and 2002, we counted 1,711 individuals representing 70 species in gap-edge habitat and 38 species in forest habitat. We detected more individuals in the gaps than in the surrounding forest during all periods for all bird groups and individual species analyzed (Table 1, Fig. 1). The abundance of forest-interior birds, field-edge birds, Blue-gray

TABLE 1. Effects of period (spring migration, breeding, postbreeding, fall migration), habitat (gap-edge and forest), and the period × habitat interaction (ANOVA) on abundance of bird species/groups detected on plot counts of gaps and forest areas in a bottomland hardwood forest in South Carolina, 2001–2002.

	Period			Habitat			Period × habitat		
Species or group	*F*	df	*P*	*F*	df	*P*	*F*	df	*P*
All birds	1.00	3,162	0.40	49.71	1,22	<0.001	0.66	3,162	0.58
Forest interior species	4.94	3,162	0.003	24.05	1,22	<0.001	0.83	3,162	0.48
Forest-edge species	2.10	3,162	0.10	60.16	1,22	<0.001	0.50	3,162	0.68
Field-edge species	27.55	3,162	<0.001	85.05	1,22	<0.001	27.90	3,162	<0.001
Blue-gray Gnatcatcher	14.08	3,162	<0.001	42.82	1,22	<0.001	5.80	3,162	0.001
Carolina Wren	9.44	3,162	<0.001	83.17	1,22	<0.001	1.76	3,162	0.16
Tufted Titmouse	12.78	3,162	<0.001	18.70	1,22	<0.001	2.22	3,162	0.088
Northern Cardinal	4.60	3,162	0.004	32.76	1,22	<0.001	0.60	3,162	0.61
Northern Parula	9.63	3,162	<0.001	19.43	1,22	<0.001	2.65	3,162	0.052
White-eyed Vireo	1.82	3,162	0.15	30.56	1,22	<0.001	1.49	3,162	0.22

Gnatcatcher, Carolina Wren, Tufted Titmouse, Northern Cardinal, and Northern Parula differed among periods, but no consistent patterns were evident, as seasonal use varied considerably by species or group (Table 1, Fig. 1).

Interactions between period and habitat type existed for field-edge birds, Blue-gray Gnatcatcher, and Northern Parula (Table 1). Field-edge birds were detected most often during spring and fall migration and primarily in gap-edge habitat (Fig. 1). The greatest proportion of forest detections of field-edge birds occurred during the postbreeding period. The Blue-gray Gnatcatcher was most abundant in gap-edge habitat during all periods, but forest detections decreased to almost zero during fall migration (Fig. 1). Northern Parula used both gap-edge and forest habitat during spring migration and the breeding period, but almost all detections were in gap-edge during the postbreeding period and fall migration (Fig. 1).

Mist Netting.—From April through October in 2001 and 2002, we captured 1,476 birds representing 56 species. We captured 55 species in gap and edge habitat, and 26 species in forest habitat across all periods. We captured more individuals in the gaps and at their edges than in the surrounding forest during all periods for all bird groups and individual species except the Carolina Wren, which was captured more frequently at edge or forest habitats than gaps during all periods (Table 2, Fig. 2). Number of captures differed among periods for all groups and species analyzed except Kentucky Warbler and Northern Cardinal, with most groups being most frequently captured during spring migration (Table 2, Fig. 2).

There was an interaction between period and habitat type, indicating a seasonal shift in habitat use, for all birds, forest-interior birds, forest-edge birds, field-edge birds, Black-throated Blue Warbler, Carolina Wren, Hooded Warbler, Kentucky Warbler, and White-eyed Vireo (Table 2). Some species (e.g., forest-interior specialists and Kentucky Warbler) shifted from gap during spring migration to edge during the breeding period and back to gap habitat after the breeding period (Fig. 3). Forest-edge birds were most abundant in the gap habitat during spring and fall migration, but both gap and edge were used equally during the breeding and postbreeding periods. Total mist-net captures tended to shift slightly between gap and edge habitat (gap during spring and fall migratory periods, edge during breeding and postbreeding), with forest captures representing just a small proportion of captures during each period. The highest proportion of forest captures, however, occurred during the breeding period (Fig. 3). Forest-interior birds, forest-edge birds, Carolina Wren, and Hooded Warbler used forested habitat most during the breeding period (Fig. 3).

DISCUSSION

We observed and captured more birds in gap and gap-edge habitat than in the surrounding mature forest during all bird-use periods. Generally, bird detections in edge habitat were more similar to detections in gap habitat than mature forest habitat. The Carolina Wren was

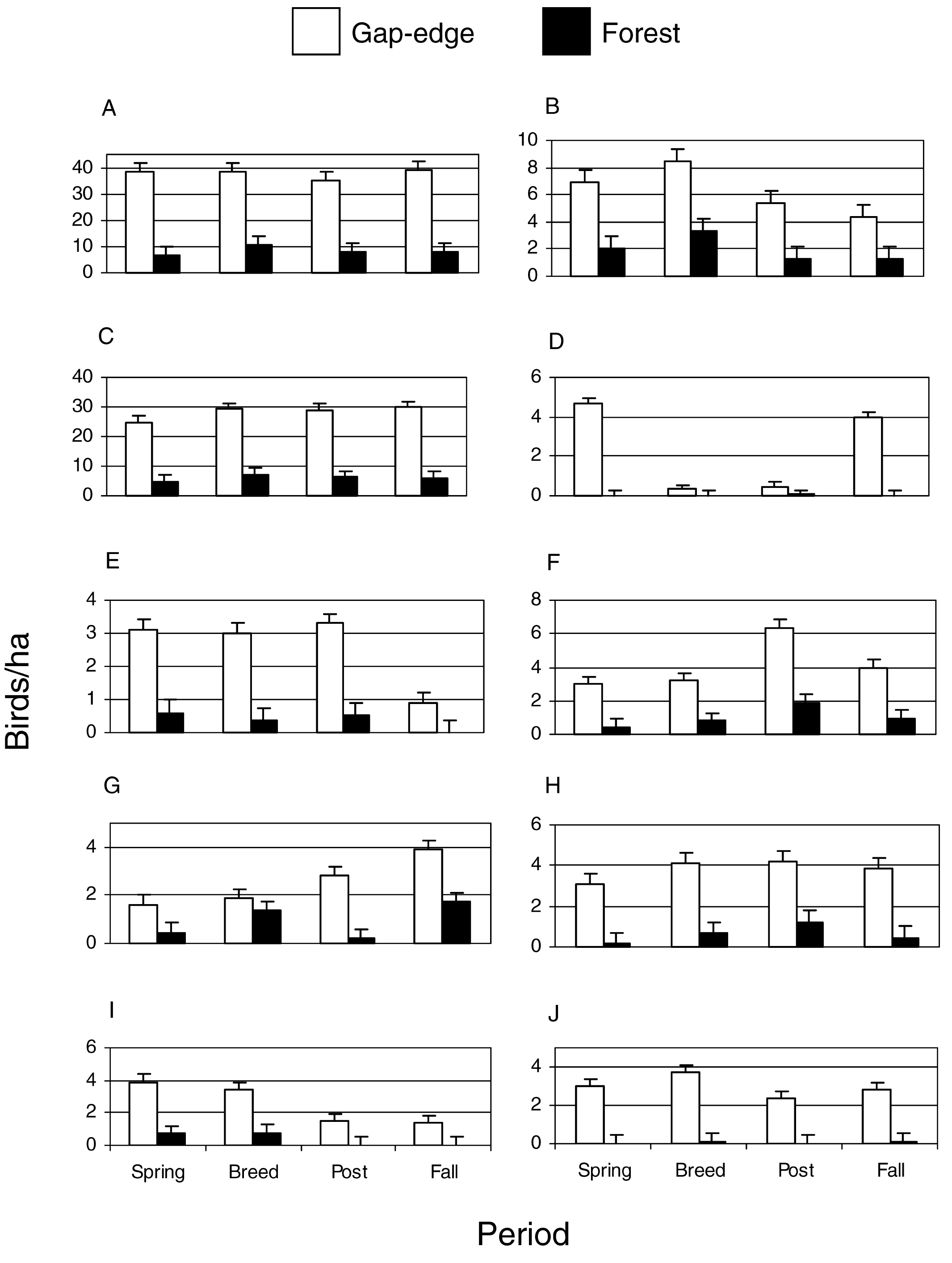


FIG. 1. Seasonal plot counts (mean birds/ha) for gap-edge (open bars) and forest habitats (filled bars), with standard error bars (2001 and 2002 in South Carolina). (A) all birds, (B) forest-interior species, (C) forest-edge species, (D) field-edge species, (E) Blue-gray Gnatcatcher, (F) Carolina Wren, (G) Tufted Titmouse, (H) Northern Cardinal, (I) Northern Parula, and (J) White-eyed Vireo.

TABLE 2. Effects of period (spring migration, breeding, postbreeding, fall migration), habitat (gap, edge, forest), and the period × habitat interaction (ANOVA) on the number of mist-net captures for bird species/groups in a bottomland hardwood forest in South Carolina, 2001–2002.

Species or group	Period			Habitat			Period × habitat		
	F	df	*P*	*F*	df	*P*	*F*	df	*P*
All birds	36.93	3,33	<0.001	43.99	2,33	<0.001	16.05	6,33	<0.001
Forest-interior species	21.87	3,33	<0.001	19.62	2,33	<0.001	6.82	6,33	<0.001
Forest-edge species	15.27	3,33	<0.001	22.45	2,33	<0.001	4.06	6,33	0.004
Field-edge species	36.94	3,33	<0.001	21.38	2,33	<0.001	7.37	6,33	<0.001
Black-throated Blue Warbler	8.64	1,66	0.005	17.91	2,66	<0.001	3.59	2,66	0.033
Carolina Wren	3.85	3,132	0.011	9.64	2,132	<0.001	1.96	6,132	0.076
Hooded Warbler	6.86	3,132	<0.001	14.73	2,132	<0.001	1.96	6,132	0.075
Kentucky Warbler	2.27	2,99	0.11	7.70	2,99	<0.001	5.50	4,99	<0.001
Northern Cardinal	2.25	3,132	0.085	12.65	2,132	<0.001	1.01	6,132	0.42
White-eyed Vireo	5.05	3,132	0.002	22.86	2,132	<0.001	1.83	6,132	0.098

the only species to show a distinct forest/edge preference, based on mist-netting captures. Other studies have reported more bird activity in early successional habitats than mature forest, including migrating foliage gleaning insectivores (Willson et al. 1982, Blake and Hoppes 1986, Martin and Karr 1986, Kilgo et al. 1999), breeding birds (Smith and Dallman 1996, Germaine et al. 1997, King et al. 2001, Moorman and Guynn 2001), and postbreeding birds (Anders et al. 1998; Vega Rivera et al. 1998, 1999, 2003; Pagen et al. 2000). Migrating birds also may prefer forest-edge habitat to forest-interior habitat during fall migration (Rodewald and Brittingham 2002). Other researchers have found that individual species, including Hooded Warbler (Annand and Thompson 1997, Robinson and Robinson 1999), Carolina Wren (Robinson and Robinson 1999, Moorman and Guynn 2001), and White-eyed Vireo (Robinson and Robinson 1999, Moorman and Guynn 2001) use regenerating group-selection openings more than mature forest during the breeding period. Hooded Warblers nest (Moorman et al. 2002) and forage (Kilgo 2005) in the mature forest understory on our site, but often were seen foraging in the gap habitat during all periods, and with young in gap habitat during the postbreeding period (LTB, pers. obs.).

It is possible that we captured more birds in gap habitat than forest habitat because of differences in habitat structure (Remsen and Good 1996). Birds using the low vegetation within the gaps were more available for sampling with a 3-m tall net than birds in the mature forest. However, our plot counts corroborated our mist-net data; they sampled both the understory and canopy, and also detected more birds using gap habitat than mature-forest habitat. Plot counts included birds using the immediate edge of gaps, a mix of habitat types and vegetation structures, which may have attracted forest-interior birds more than the actual gap center. Ease of detection of birds in gaps during plot counts likely was lower than in the forest because of the dense vegetation in the gaps and our estimates of bird use of gaps may be conservative.

While most birds used gap and edge habitat more than forested habitat during all periods, we also detected a seasonal shift in habitat use for several groups, as evidenced by interac-

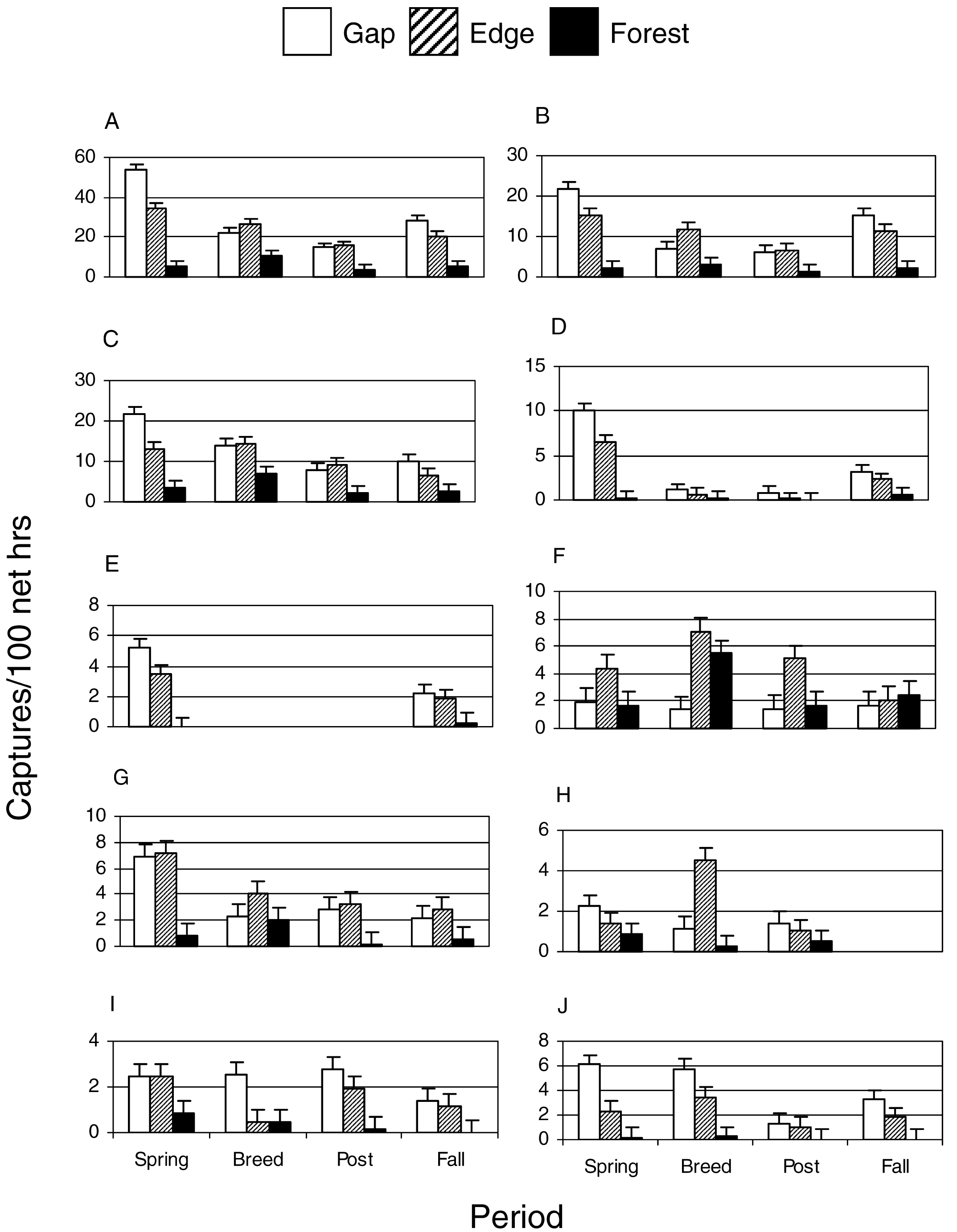


FIG. 2. Mean bird captures/100 net hrs for each habitat and period with standard error bars (2001 and 2002 in South Carolina). (A) all birds, (B) forest-interior species, (C) forest-edge species, (D) field-edge species, (E) Black-throated Blue Warbler, (F) Carolina Wren, (G) Hooded Warbler, (H) Kentucky Warbler, (I) Northern Cardinal, and (J) White-eyed Vireo.

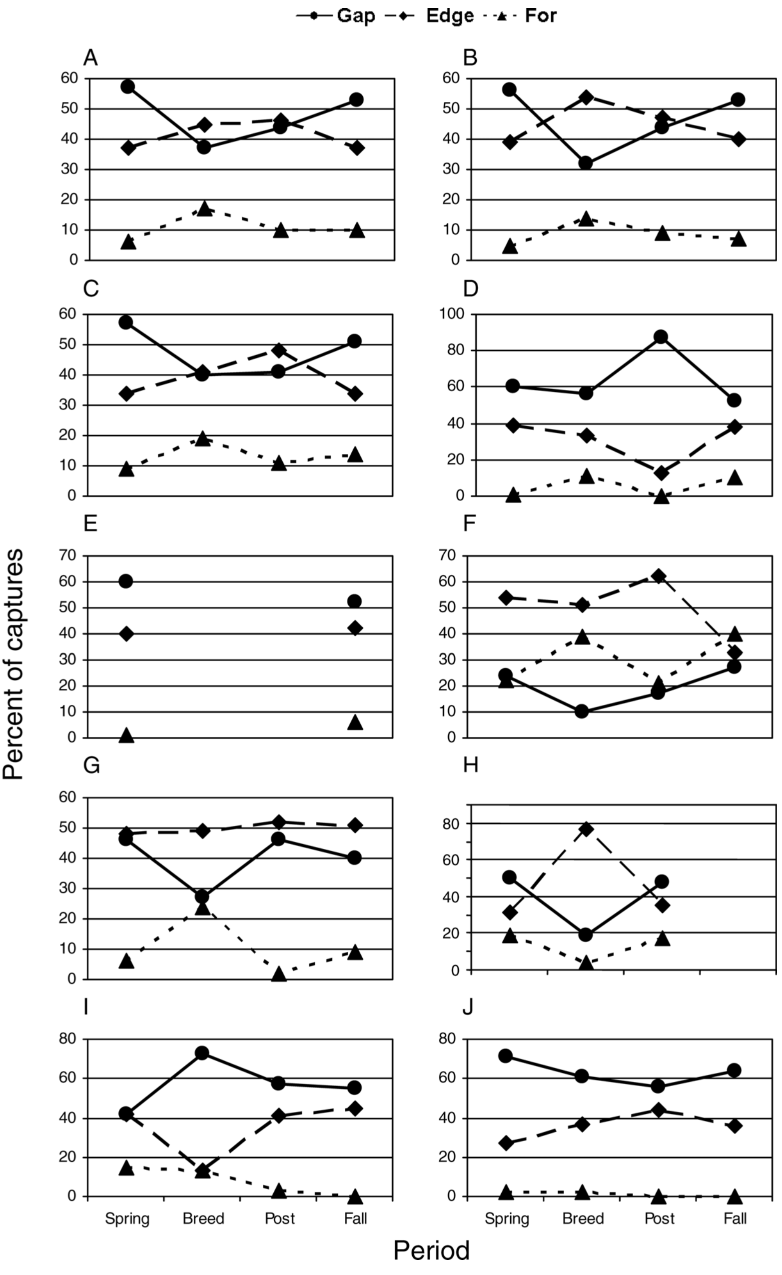


FIG. 3. Percent of mist-net captures per period occurring in each habitat type (gap, edge, forest) in a bottomland forest (2001 and 2002 in South Carolina). (A) all birds, (B) forest-interior species, (C) forest-edge species, (D) field-edge species, (E) Black-throated Blue Warbler, (F) Carolina Wren, (G) Hooded Warbler, (H) Kentucky Warbler, (I) Northern Cardinal, and (J) White-eyed Vireo.

tions between period and habitat; the relative proportions of gap, edge, and forest captures varied among periods. Generally, bird use of gap and edge habitats was highest during spring and fall migration, while use of forested habitat tended to be greatest during the breeding period and lowest during the migratory periods. Other research has documented seasonal shifts in habitat use between the breeding and postbreeding periods, particularly as fledgling birds moved from forested habitat into early- and mid-successional habitats (Anders et al. 1998; Vega Rivera et al. 1998, 2003; Pagen et al. 2000), possibly in search of greater cover or more abundant food resources. Regenerating forest canopy gaps may provide a necessary habitat type for birds during seasons of increased mobility.

Gap interiors were not only densely vegetated, but also contained early successional fruiting species (e.g., winged sumac [*Rhus copallina*] and blackberry), while other fruiting species such as poison ivy (*Toxicodendron radicans*) and hawthorn (*Crataegus* spp.) were common at the immediate gap edge (LTB, pers. obs.). We observed omnivorous birds eating fruits in gaps, including American beautyberry (*Callicarpa americana*), flowering dogwood (*Cornus florida*), grape (*Vitis* sp.), hawthorn, poison ivy, and winged sumac (LTB, pers. obs.). Fruit typically is most abundant from late summer through early fall (McCarty et al. 2002). Willson et al. (1982) reported that avian frugivores preferentially visited natural forest openings during migratory periods, even when these gaps provided no more fruit than surrounding forest habitat. We did not, however, find a corresponding shift in habitat use for omnivorous species such as Northern Cardinal, suggesting that birds were meeting their nutritional needs without closely following seasonal fruit availability.

Birds used regenerating canopy gaps more than mature forested habitat during all periods. Bird habitat use shifted slightly from gaps during spring migration to forest during the breeding period, then back to gaps during the postbreeding period and fall migration. Reasons for these habitat selections and seasonal shifts, however, remain speculative. It is possible that omnivorous birds use canopy gaps more during periods of high fruit availability, as canopy gaps are known for their high fruit abundance (Levey 1990). However, fruit production within our canopy gaps was relatively low and highly seasonal, with no fruit available during spring, one of the periods of highest bird use. We suspect birds may select regenerating canopy gaps for the protection offered by these densely vegetated areas, particularly during periods of vulnerability, such as during migration when birds move through unfamiliar areas and during the postfledging period when young are more vulnerable to predators. Alternatively, birds could be tracking seasonal changes in the abundance of arthropod food resources, if the relative abundance of arthropods in gaps and forest habitat changes through the year. Additional work is needed to assess the relative importance of vegetation structure and arthropod abundance in affecting seasonal avian habitat use in southeastern forests.

The creation of 0.13- to 0.5-ha canopy gaps can increase habitat diversity within mature bottomland hardwood forest, thereby attracting a greater number of foraging, breeding, and migrating birds. This practice may be particularly beneficial in stands with a sparse understory because of dense canopy closure, a condition common to the mid-successional forests that dominate the southeastern United States. Our gaps did not impact reproductive success of Hooded Warblers nesting in the surrounding forest (Moorman et al. 2002), probably because of the extensive amount of forest cover in the landscape (i.e., the extent of forest fragmentation is low). Further, Robinson and Robinson (1999) noted that long-term effects of small-scale canopy gaps on the forest bird community are unlikely because the regenerating forest matures and returns to pre-harvest conditions in a relatively short time. When the gaps we studied were 2–5 years old (Kilgo et al. 1999, Moorman and Guynn 2001), their contrast with the surrounding forest, in terms of vegetation height and structure, was dramatic. During the current study, the gaps were 7–8 years old and the contrast was beginning to blur, with many gaps more closely resembling the surrounding forest than 3-year-old gaps; some saplings exceeded 10 m in height.

Group-selection timber harvest could allow generation of income concurrent with an increase in habitat diversity, especially in forests where rates of natural canopy-gap creation have been altered by prior human disturbance (e.g., fire suppression, even-aged timber harvest, altered flooding regimes). Pashley and Barrow (1993) recommended a management regime that mimics natural disturbance to maintain habitat heterogeneity. Our results highlight the importance of this recommendation, as birds used both forested and early successional habitat at different times during the year.

ACKNOWLEDGMENTS

Financial support for this project was provided by the USDA CSREES National Research Initiative Competitive Grants Program (Award 00-35101-9307), North Carolina State University, and the U.S. Forest Service Southern Research Station. We thank the U.S. Department of Energy—Savannah River for providing access to the study site and the U.S. Forest Service—Savannah River for logistical support, with special thanks to J. I. Blake and E. G. Olson. We thank R. A. Lancia, D. J. Robison, and T. R. Simons for reviewing this manuscript. We are grateful for field assistance from T. B. Champlin, S. M. Junker, K. M. Mack, and D. E. Westerman, and for statistical assistance from S. B. Donaghy, M. L. Gumpertz, and J. L. Sloan.

LITERATURE CITED

ANDERS, A. D., J. FAABORG, AND F. R. THOMPSON, III. 1998. Postfledging dispersal, habitat use, and home-range size of juvenile Wood Thrushes. Auk 115:349–358.

ANNAND, E. M. AND F. R. THOMPSON, III. 1997. Forest bird response to regeneration practices in central hardwood forests. Journal of Wildlife Management 61:159–171.

BLAKE, J. G. AND W. G. HOPPES. 1986. Influence of resource abundance on use of tree-fall gaps by birds in an isolated woodlot. Auk 103:328–340.

CANHAM, C. D., J. S. DENSLOW, W. J. PLATT, J. R. RUNKLE, T. A. SPIES, AND P. S. WHITE. 1990. Light regimes beneath closed canopies and tree-fall gaps in temperate and tropical forests. Canadian Journal of Forest Research 20:620–631.

EHRLICH, P. R., D. S. DOBKIN, AND D. WHEYE. 1988. The birder's handbook: a field guide to the natural history of North American birds. Simon and Schuster, New York, USA.

GERMAINE, S. S., S. H. VESSEY, AND D. E. CAPEN. 1997. Effects of small forest openings on the breeding bird community in a Vermont hardwood forest. Condor 99:708–718.

HAMEL, P. B. 1992. Land manager's guide to the birds of the South. The Nature Conservancy, Chapel Hill, North Carolina, USA.

HOLMES, R. T., R. E. BONNEY, JR., AND S. W. PACALA. 1979. Guild structure of the Hubbard Brook bird community: a multivariate approach. Ecology 60: 512–520.

HUNTER, W. C., D. A. BUEHLER, R. A. CANTERBURY, J. L. CONFER, AND P. B. HAMEL. 2001. Conservation of disturbance-dependent birds in eastern North America. Wildlife Society Bulletin 29:440–455.

KILGO, J. C. 2005. Harvest-related edge effects on prey availability and foraging of Hooded Warblers in a bottomland hardwood forest. Condor 107:626–635.

KILGO, J. C., K. V. MILLER, AND W. P. SMITH. 1999. Effects of group-selection timber harvest in bottomland hardwoods on fall migrant birds. Journal of Field Ornithology 70:404–413.

KING, D. I., R. M. DEGRAAF, AND C. R. GRIFFIN. 2001. Productivity of early successional shrubland birds in clearcuts and groupcuts in an eastern deciduous forest. Journal of Wildlife Management 65:345–350.

LEVEY, D. J. 1990. Habitat-dependent fruiting behaviour of an understory tree, *Miconia centrodesma*, and tropical treefall gaps as keystone habitats for frugivores in Costa Rica. Journal of Tropical Ecology 6:409–420.

MARTIN, T. E. AND J. R. KARR. 1986. Patch utilization by migrating birds: resource oriented? Ornis Scandanavia 17:165–174.

MCCARTY, J. P., D. J. LEVEY, C. H. GREENBERG, AND S. SARGENT. 2002. Spatial and temporal variation in fruit use by wildlife in a forested landscape. Forest Ecology and Management 164:277–291.

MOORE, F. R., S. A. GAUTHREAUX, JR., P. KERLINGER, AND T. R. SIMONS. 1993. Stopover habitat: management implications and guidelines. Pages 58–69 *in* Status and management of neotropical migratory birds (D. Finch and P. Stangel, Editors). General Technical Report RM-229. USDA, Forest Service, Fort Collins, Colorado, USA.

MOORMAN, C. E. AND D. C. GUYNN, JR. 2001. Effects of group-selection opening size on breeding bird habitat use in a bottomland forest. Ecological Applications 11:1680–1691.

MOORMAN, C. E., D. C. GUYNN, JR., AND J. C. KILGO. 2002. Hooded Warbler nesting success adjacent to group-selection and clearcut edges in a southeastern bottomland forest. Condor 104:366–377.

PAGEN, R. W., F. R. THOMPSON, III, AND D. E. BURHANS. 2000. Breeding and post-breeding habitat use by forest migrant songbirds in the Missouri Ozarks. Condor 102:738–747.

PASHLEY, D. N. AND W. C. BARROW. 1993. Effects of land use practices on neotropical migratory birds in bottomland hardwood forests. Pages 315–320 *in* Status and management of neotropical migratory birds (D. Finch and P. Stangel, Editors). General Technical Report RM-229. USDA, Forest Service, Fort Collins, Colorado, USA.

PETIT, D. R. 2000. Habitat use by landbirds along Nearctic-neotropical migration routes: implications for conservation of stopover habitats. Studies in Avian Biology 20:15–33.

PYLE, P. 1997. Identification guide to North American passerines. Part I. Slate Creek Press, Bolinas, California, USA.

REMSEN, JR., J. V. AND D. A. GOOD. 1996. Misuse of data from mist-net captures to assess relative abundance in bird populations. Auk 113:381–398.

ROBINSON, S. K. AND R. T. HOLMES. 1982. Foraging

behavior of forest birds and the relationships among search tactics, diet, and habitat structure. Ecology 63:1918–1931.
ROBINSON, W. D. AND S. K. ROBINSON. 1999. Effects of selective logging on forest bird populations in a fragmented landscape. Conservation Biology 13:58–66.
RODEWALD, P. G. AND M. C. BRITTINGHAM. 2002. Habitat use and behavior of mixed species landbird flocks during fall migration. Wilson Bulletin 114: 87–98.
SAS INSTITUTE, INC. 1990. SAS user's guide. 6. SAS Institute, Inc., Cary, North Carolina, USA.
SMITH, R. AND M. DALLMAN. 1996. Forest gap use by breeding Black-throated Green Warblers. Wilson Bulletin 108:588–591.
VEGA RIVERA, J. H., W. J. MCSHEA, AND J. H. RAPPOLE. 2003. Comparison of breeding and postbreeding movements and habitat requirements for the Scarlet Tanager (*Piranga olivacea*) in Virginia. Auk 120:632–644.
VEGA RIVERA, J. H., W. J. MCSHEA, J. H. RAPPOLE, AND C. A. HAAS. 1999. Postbreeding movements and habitat use of adult Wood Thrushes in northern Virginia. Auk 116:458–466.
VEGA RIVERA, J. H., J. H. RAPPOLE, W. J. MCSHEA, AND C. A. HAAS. 1998. Wood Thrush postfledging movements and habitat use in northern Virginia. Condor 100:69–78.
WATT, A. S. 1947. Pattern and process in the plant community. Journal of Ecology 35:1–22.
WILLSON, M. F., E. A. PORTER, AND R. S. CONDIT. 1982. Avian frugivore activity in relation to forest light gaps. Caribbean Journal of Science 18:1–6.

IAPPENDIX. Observed bird species and their habitat group associations. Species included were detected by plot counts or mist-netting at least once (South Carolina, 2001–2002).

Species	Scientific name	Habitat group
Turkey Vulture	*Cathartes aura*	field edge
Red-shouldered Hawk	*Buteo lineatus*	forest edge
Mourning Dove	*Zenaida macroura*	field edge
Yellow-billed Cuckoo	*Coccyzus americanus*	forest edge
Barred Owl	*Strix varia*	forest interior
Ruby-throated Hummingbird	*Archilochus colubris*	forest edge
Red-headed Woodpecker	*Melanerpes erythrocephalus*	forest edge
Red-bellied Woodpecker	*Melanerpes carolinus*	forest edge
Downy Woodpecker	*Picoides pubescens*	forest edge
Hairy Woodpecker	*Picoides villosus*	forest interior
Northern Flicker	*Colaptes auratus*	forest edge
Pileated Woodpecker	*Dryocopus pileatus*	forest interior
Eastern Wood-Pewee	*Contopus virens*	forest edge
Acadian Flycatcher	*Empidonax virescens*	forest interior
Eastern Phoebe	*Sayornis phoebe*	forest edge
Great Crested Flycatcher	*Myiarchus crinitus*	forest edge
White-eyed Vireo	*Vireo griseus*	forest edge
Yellow-throated Vireo	*Vireo flavifrons*	forest edge
Blue-headed Vireo	*Vireo solitarius*	forest interior
Red-eyed Vireo	*Vireo olivaceus*	forest interior
Blue Jay	*Cyanocitta cristata*	forest edge
American Crow	*Corvus brachyrhynchos*	forest edge
Fish Crow	*Corvus ossifragus*	forest edge
Carolina Chickadee	*Poecile carolinensis*	forest edge
Tufted Titmouse	*Baeolophus bicolor*	forest edge
White-breasted Nuthatch	*Sitta carolinensis*	forest edge
Brown-headed Nuthatch	*Sitta pusilla*	forest edge
Carolina Wren	*Thryothorus ludovicianus*	forest edge
Blue-gray Gnatcatcher	*Polioptila caerulea*	forest edge
Veery	*Catharus fuscescens*	forest interior
Gray-cheeked Thrush	*Catharus minimus*	forest interior
Bicknell's Thrush	*Catharus bicknelli*	forest interior
Swainson's Thrush	*Catharus ustulatus*	forest interior
Hermit Thrush	*Catharus guttatus*	forest interior
Wood Thrush	*Hylocichla mustelina*	forest interior
Gray Catbird	*Dumetella carolinensis*	field edge
Brown Thrasher	*Toxostoma rufum*	field edge

APPENDIX. Continued.

Species	Scientific name	Habitat group
Blue-winged Warbler	*Vermivora pinus*	field edge
Golden-Winged Warbler	*Vermivora chrysoptera*	forest edge
Northern Parula	*Parula americana*	forest edge
Chestnut-sided Warbler	*Dendroica pensylvanica*	field edge
Magnolia Warbler	*Dendroica magnolia*	forest interior
Black-throated Blue Warbler	*Dendroica caerulescens*	forest interior
Yellow-rumped Warbler	*Dendroica coronata*	forest edge
Black-throated Green Warbler	*Dendroica virens*	forest interior
Pine Warbler	*Dendroica pinus*	forest edge
Prairie Warbler	*Dendroica discolor*	field edge
Black-and-white Warbler	*Mniotilta varia*	forest interior
American Redstart	*Setophaga ruticilla*	forest interior
Worm-eating Warbler	*Helmitheros vermivorum*	forest edge
Swainson's Warbler	*Limnothlypis swainsonii*	forest interior
Ovenbird	*Seiurus aurocapilla*	forest interior
Northern Waterthrush	*Seiurus noveboracensis*	forest interior
Louisiana Waterthrush	*Seiurus motacilla*	forest interior
Kentucky Warbler	*Oporornis formosus*	forest interior
Common Yellowthroat	*Geothlypis trichas*	field edge
Hooded Warbler	*Wilsonia citrina*	forest interior
Canada Warbler	*Wilsonia canadensis*	forest interior
Yellow-breasted Chat	*Icteria virens*	field edge
Summer Tanager	*Piranga rubra*	forest edge
Scarlet Tanager	*Piranga olivacea*	forest interior
Eastern Towhee	*Pipilo erythrophthalmus*	field edge
Northern Cardinal	*Cardinalis cardinalis*	forest edge
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	forest interior
Indigo Bunting	*Passerina cyanea*	field edge
Common Grackle	*Quiscalus quiscula*	field edge
Brown-headed Cowbird	*Molothrus ater*	forest edge

RIPARIAN FOREST WIDTH AND THE AVIAN COMMUNITY

IN A GREENBELT CORRIDOR SETTING

Karl W. Hoffman, B.S

Thesis prepared for the Degree of

MASTER OF SCIENCE

UNIVERSITY OF NORTH TEXAS

May 2001

APPROVED:

Kenneth Dickson, Major Professor
Ken Stigman, Committee Member
Earl Zimmerman, Committee Member and
Chair of the Department of Biological
Sciences
C. Neal Tate, Dean of the Robert B.
Toulouse School of Graduate Studies

Karl W. Hoffman, Riparian Forest Width and the Avian Community in a Greenbelt Corridor Setting. Master of Science (Environmental Science), 60 pp.

The forest avian community of the Ray Roberts Greenbelt (Denton Co., Texas) was characterized for two years using point count station sampling, from fall 1998 to summer 2000. Richness data for both breeding seasons were correlated with two-spatial metrics: width of the riparian forest and distance to the nearest edge. There were significant correlations between forest interior species richness and both spatial metrics, for both breeding seasons. Based on these data, a minimum riparian forest width threshold of 400-meters is suggested to provide habitat for forest interior species, which have lost considerable habitat through forest fragmentation. Partners in Flight breeding bird priority concern scores were used to create a habitat priority index for the Trinity River bottomland hardwood forest system.

ACKNOWLEDGMENTS

This study was a part of a larger cooperative effort between the University of North Texas Institute of Applied Sciences, the Ft. Worth U.S. Army Corps of Engineers, and the U.S. COE Waterways Experiment Station. Special thanks go to Dr. Ken Dickson, Dr. Richard Fischer, Dr Earl Zimmerman, and Dr. Doug Elrod for project support, and to Dr. Ken Steigman, who provided the birding field expertise and training. Thanks to Sonny Solis of the Texas Parks and Wildlife for permission to carry out this study in his management area, and also for logistical support. Thanks to Dr. Dwight Barry for help in experimental design and implementation, and for providing GIS and GPS expertise. Thanks to Michael Guilfoyle for added birding training, and for valuable advice concerning habitat guilds. Thanks to Carla Carr, Mike Kavanaugh, and Jason Taylor for logistical support (including pulling my truck out of the mud).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

INTRODUCTION

Riparian forest systems have become important in the last several decades in terms of water quality buffers against land use practices such as agriculture, silviculture and logging operations, and as wildlife conservation corridors (Keller et al 1993). Researchers have found riparian forests to be extremely important for avian communities, especially for area-sensitive Neotropical migrant and resident breeding species (Ehrlich et al 1988). However, depending on the width of the riparian forest in question, edge effects may preclude habitat quality for species requiring forest interior for their life history requirements, for example forest interior breeding bird species (Kilgo et al 1998). Past land use practices have reduced the forest in many riparian areas to little more than narrow strips, connecting what are often small forest patches. Southeastern bottomland hardwood forest systems have been reduced by at least 50% since colonization by western Europeans in the mid 1800s (Kilgo et al 1998).

Many Neotropical migrant species in are known to be in decline, due to loss in wintering habitat in tropical South America and to loss of breeding habitat in North America (Ehrlich et al 1988). Loss of cover and foraging resources along migration flyways are problems for Neotropical migrant species as well (Leahy 1982). Narrow forest strips do provide habitat, especially for forest/edge species. However, riparian forest corridors, which may be of considerable area due to length, may lack quality interior habitat conditions required by forest interior species (Kilgo et al 1998). Narrow strips have a large edge to volume ratio, which may give tactical advantage such edge species as Brown-headed Cowbirds, which are nest parasites, cavity nest competitors such as European Starlings (Ehrlich et al 1988), and to nest predators such as American Crows and Blue Jays (Haegen and DeGraaf 1996).

Conservation efforts for forest birds should focus on forest interior breeding species rather than on forest/edge breeding species, as the latter are generalists that are adapted to disturbed and transitional habitats, and tend to thrive under the influence of man (Robbins et al 1989).

OBJECTIVES

Objective One

Sampling is designed to characterize avian community composition, using the point-count station method, in the riparian forest of the Lake Ray Roberts Greenbelt Corridor. Descriptive statistics will be generated for each of the eight sampling seasons. Data collected during both breeding seasons will be statistically analyzed to test the following hypothesis:

1-Ho: There is no significant correlation between forest interior avian species richness and forest width.

1-Ha: There is a significant correlation between forest interior avian species richness and forest width.

2-Ho: There is no significant correlation between forest interior species richness and distance to the nearest edge.

2-Ha: There is a significant correlation between forest interior species richness and distance to the nearest edge.

Objective Two

Partners In Flight priority concern scores for the National PIF *Oaks and Prairies* physiographic region (#08) will be used to create a rank order *habitat priority index* with a combined breeding bird list for the 1999 and 2000 seasons, adapted from the method recommended by Carter et al (1996). The rank order priority index, representing bottomland hardwood forest habitat, will be examined in terms of avian habitat guilds and migration status for the species included, and compared to Texas PIF priority bird lists for the region.

LITERATURE REVIEW

Riparian Forest Width and the Avian Community

Several studies have been conducted in various regions of North America to explore the relationships between riparian forest width and avifauna communities, in different surrounding land-use scenarios.

Thurmond et al. (1995) studied the importance of streamside management zones (SMZs) in maintaining avifauna diversity in Georgian Upper Coastal Plain landscapes dominated by young loblolly pine plantations. SMZs are designed primarily to protect water quality from detrimental effects of silviculture. SMZ width classes (50ft, 100ft, and 164ft) were sampled for breeding and wintering avifauna abundance and diversity. They concluded that even the widest class SMZs did not provide suitable habitat for forest interior Neotropical migrants, which were essentially absent.

Kinley and Newhouse (1997) recommended riparian management areas averaging 70m wide for maintaining near-natural densities of riparian-associated birds in the Montane Spruce zone of British Columbia: an area that is harvested for timber.

Hagar (1999) studied the effects of riparian buffer width of headwater streams in Western Oregon on forest-associated avian species' abundances. She suggested that in the context of logging operations, buffer zones should be wider than 40m, though habitat may not be provided for species needing closed canopy, upland interior forests.

Whitaker and Montevecci (1999) compared breeding bird assemblages (within five habitat guilds) between undisturbed shorelines and 20-50 m wide riparian buffer strips of balsam fir in Newfoundland, Canada. They found that in this area of intensive clear cutting, forest interior species were rare in even the widest strips compared to local forest interior habitat.

Keller et al (1993) researched the probability of presence of avian species with riparian forest width in agricultural Delaware and Maryland. They found that presence of several species of Neotropical migrants did correlate with forest width, and recommended riparian forest widths of at least 100 m to provide nesting habitat for area-sensitive species.

Kilgo (1998) compared breeding bird abundance indices and species richness among bottomland hardwood stands surrounded with pine plantations and/or scrubland. Widths of the stands, which were in the Savannah River area of South Carolina, ranged from <50 m to >1,000 m. He concluded that though narrow riparian corridors can support an abundant and diverse avian population, riparian zones of at least 500 m in width are necessary to maintain a complete avifauna community characteristic of South Carolina bottomland hardwood forests.

Hodges and Krementz (1996) investigated the relationship between riparian forest corridor width with Neotropical breeding bird community diversity and abundance along the lower Altamaha River area in Georgia. They recommended that if Neotropical breeding bird communities are to be a conservation target group, 100 m wide riparian zone buffer strips in pine plantation setting were needed to maintain a functional community assemblage.

Barry (2000), who participated in this study of the Ray Roberts Greenbelt, compared the two years of breeding season with forest spatial metric data by delineating the Greenbelt forest into two types: *corridors* and *patches*. Any point count stations that were within 100 meters of an edge were considered to be within corridors, and those that were not within the 100-meter edge *buffer* were considered to be within patches. He found that patches were better suited for supporting forest interior species in terms of both species richness and abundance, and based on these data recommended a threshold of 35% forest cover within a kilometer of any given point in the Greenbelt study area. Barry also recommends a maximum corridor length between patches of 250m, and a minimum corridor width of 200-meters. He also recommended that patches should have a high volume to edge ratio whenever possible.

Partners in Flight (PIF)

In response to a marked decline in Neotropical migrants in the North America, a conservation organization known as Partners in Flight (PIF) was created in 1990. The central premise of PIF is that "the resources of public and private organizations in North and South America must be combined, coordinated, and increased in order to achieve success in conserving bird populations in this hemisphere." PIF is a cooperative effort between local and federal agencies, state Fish and Wildlife agencies, universities, the U.S. military, non-government agencies, and the forest industry (Partners in Flight-U.S. Homepage 2000).

Breeding Bird Survey data, compiled by Robbins et al and published in 1986, were used to partition all of North America north of Mexico into breeding bird physiographic areas (Carter et al 2000)(see Figure 1). Within these physiographic areas, all non-game land birds have been assigned *priority concern scores*, based on the PIF species prioritization process. Priority concern scores are the sums of scores assigned to each breeding species for seven variables or parameters of 'vulnerability'; *Breeding Distribution* (BD), *Non-breeding Distributio*n (ND), *Relative Abundanc*e (RA), *Threats* *to Breeding* (TB), *Threats to Non-breeding* (TN), *Population Trend* (PT), and *Area Importance* (AI)(Carter et al 2000). Parameter scores range from one to five.

Global scores, which remain consistent over each species entire range, are given to the first three parameters (BD, ND, and RA). The next three parameters (TB, TN, and PT) are also considered global, but may be adjusted to local conditions if more appropriate data apply. The final parameter, (IA), is assigned to each species in each physiographic area independently. Summed scores for each variable give species a potential priority concern score range of seven to thirty-five (Carter et al 1996).

The PIF database, which is maintained and made publicly available by the Colorado Bird Observatory, is intended to guide avian conservation efforts through habitat prioritization in North America (Colorado Bird Observatory PIF Database 2000).

Texas Partners in Flight, a part of the Texas Parks and Wildlife Department's Wildlife Diversity Branch, has further refined the physiographic regions within the state into state *ecoregions* (see Figure 2). Texas PIF publishes avian conservation priority lists for habitat types within each ecoregion, but does not attempt to recalculate priority concern scores for avian species. Unfortunately, the physiographic regions drawn by the National PIF, and the ecoregions of the Texas PIF do not agree for the study site area, so there is some confusion as to the priority concern scores to be used in the Denton County area.

The study site is on the eastern boundary of the *Osage Plains* ecoregion ('the Cross Timbers') as delineated by Texas PIF, and is just outside the western boundary for the *Oaks and Prairies* ecoregion ('The Post Oak Savannahs and Blackland Prairies') (Shackelford and Lockwood 2000). Denton County falls within the *Oaks and Prairies* physiographic area (#33) as defined by the National PIF (Fitzgerald et al 2000). The

National PIF has published *Bird Conservation Plans* for some of its physiographic areas, including the *Osage Plains* area (#33), which lies to the north and west of the study area by perhaps 100 kilometers (see Figure 3). As of yet, a Conservation Plan for the *Oaks and Prairies* area (#08) has not been formulated.

Therefore, this study will examine the priority conservation bird lists for ‘riparian forest’ and ‘bottomland hardwood forest’ habitats within the Texas PIF *Osage Plains* and *Oaks and Prairies* ecoregions, and the overall Texas ‘declining bird priority concern list’. Also, the National PIF Bird Conservation Plan for its *Osage Plains* physiographic area (#33), as it applies to bottomland hardwood forests, will be noted.

Figure 1. National PIF physiographic regions (Partners in Flight – U.S. Homepage 2000).

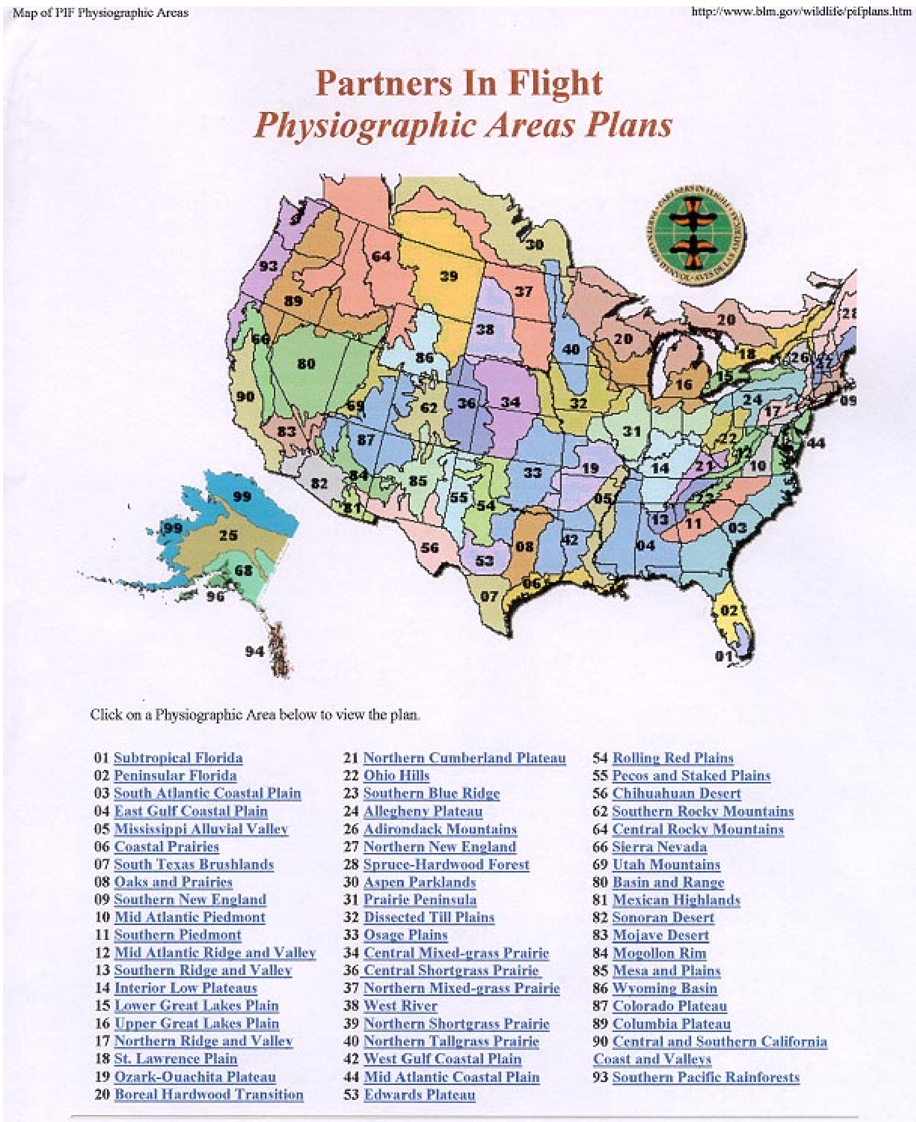


Figure 2. Texas PIF ecoregions (Shackelford and Lockwood 2000).

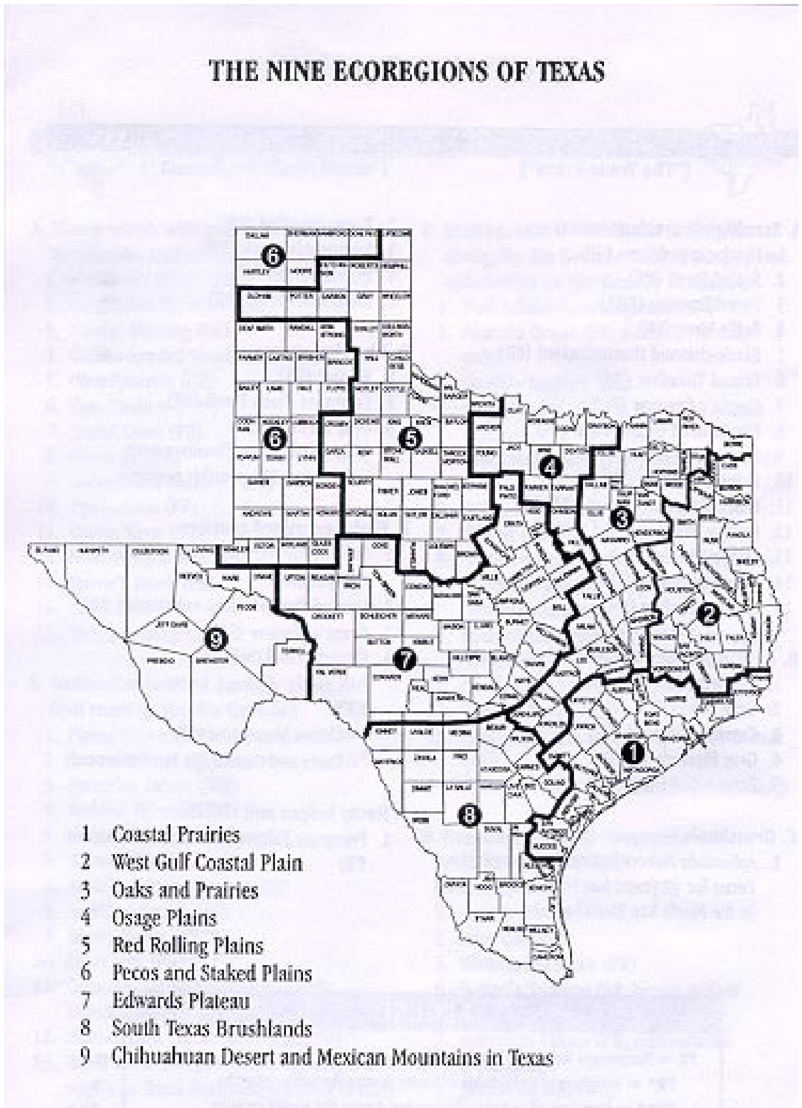
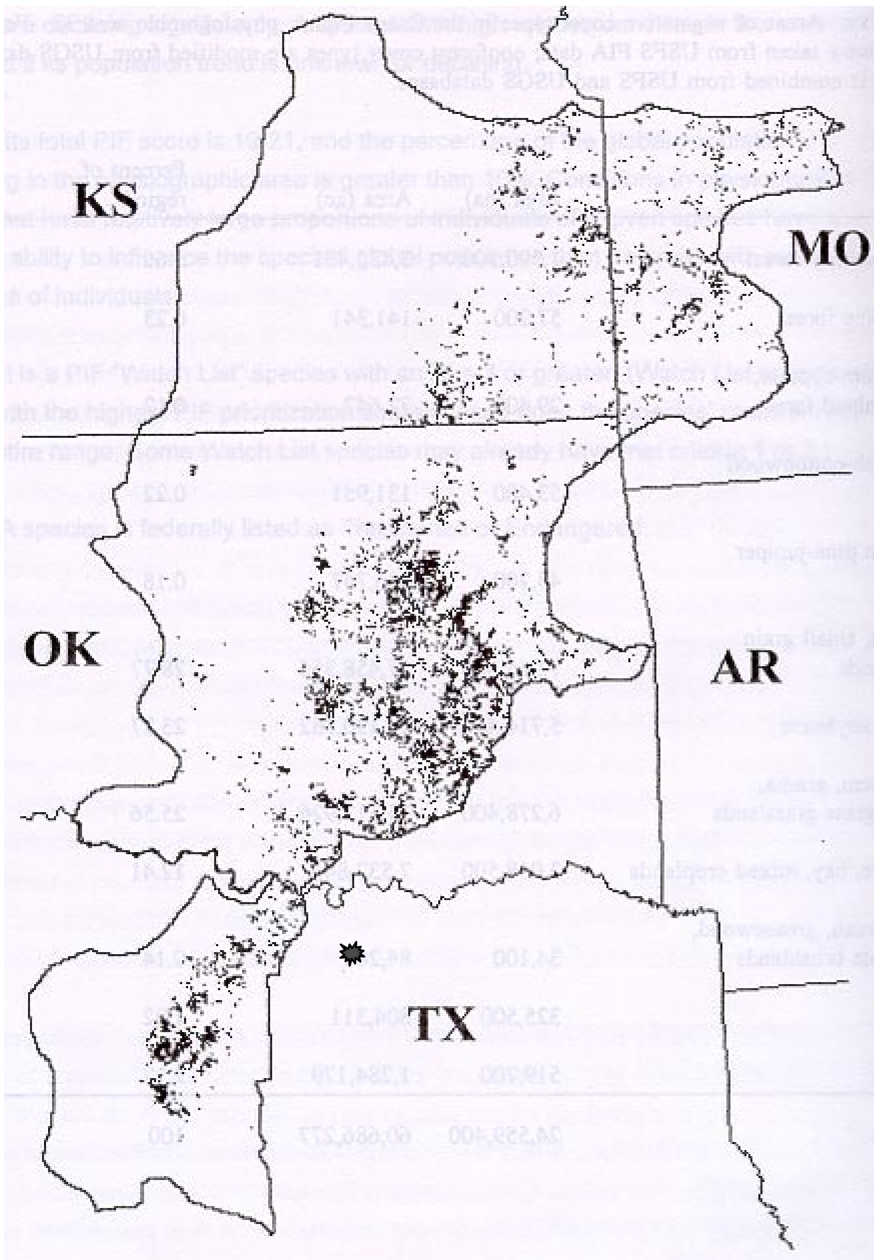


Figure 3. National Partners in Flight Osage Plains physiographic region (#33), and approximate location of the Ray Roberts Greenbelt study area. Adapted from Fitzgerald et al, 2000.



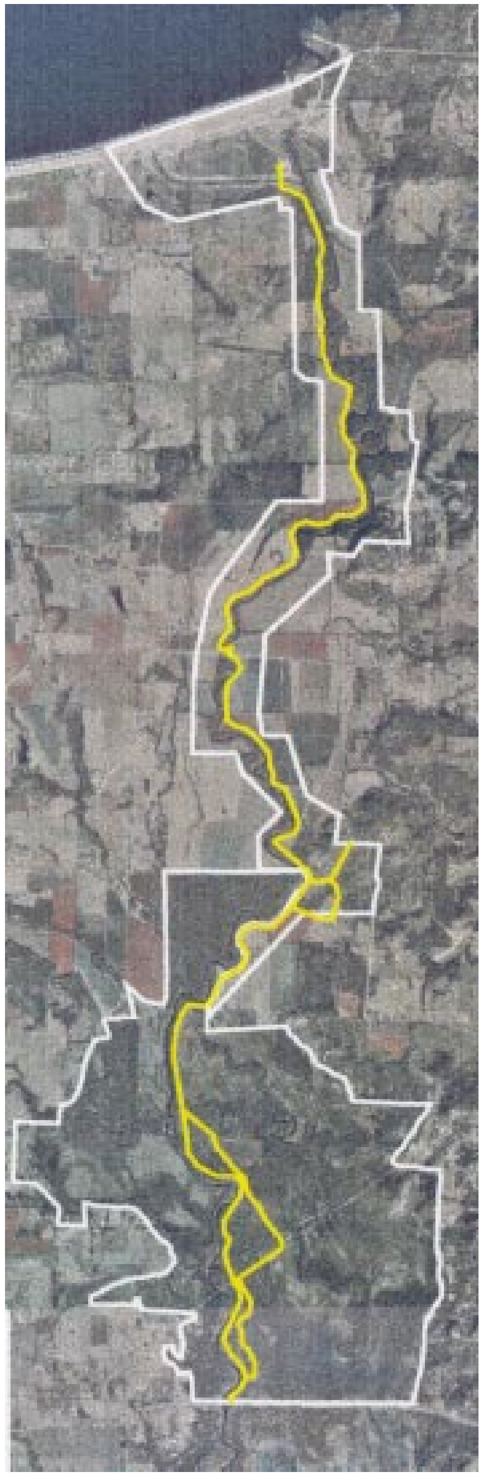
STUDY AREA

The Ray Roberts Greenbelt consists of approximately 1600 hectares (4,000 acres) of primarily bottomlands along the Elm Fork, Trinity River in Denton County, Texas, between Lake Ray Roberts to the north, and Lewisville Lake to the south (see Figure 4). The study area is about 16 kilometers (ten miles) in length. Owned by the Army Corps of Engineers and managed by the Texas Parks and Wildlife Department, the Greenbelt is a multi-use facility, managed primarily for wildlife conservation and recreation. Southeastern bottomland hardwood forest comprises about 60% of the study area. The land surrounding the Ray Roberts Greenbelt is used predominantly for agriculture, including croplands, hayfields, and pasture for cattle and horses.

The forest consists of a mixture of narrow corridors and patches of various widths and sizes. The patches vary in size from 8 hectares (20 acres) to 80 hectares (200 acres). The remainder of the Greenbelt consists mainly of oldfield and of the Trinity River itself. The forest is a matrix of successional stages, including young and mature forest, and also contains some of the only remaining old growth forest in North Central Texas. Common tree species include Hackberry species, Green ash, Bois d' Arc, Eastern Cottonwood, and several Elm and Oak species.

Geographically, the Ray Roberts Greenbelt is situated between the Osage Plains and the Blackland Prairie of North Central Texas, and is at the western extreme of the southeastern bottomland hardwood forest system.

Figure 4. The Ray Roberts Greenbelt; Denton County, Texas. The hike and bike trail is shown in yellow, and the COE property boundary in white.



METHODS

Field Sampling

Avian species richness studies covered the 1998 fall migration season, the 1998-1999 winter resident season, the 1999 spring migration, the 1999 summer breeding season, the 1999 fall migration season, the 1999-2000 winter resident season, the 2000 spring migration, and the 2000 summer resident season. A set of 62 permanent point count stations was situated along a stratified transect line within the riparian corridor and forest patches. The stations were spaced 250-m apart to insure that double counting of individual birds was minimalized. The transect line was placed so that point count stations were equally distant from the forest edges perpendicular to the Trinity River. Point count stations were marked with bright flagging to facilitate timely location during field sampling. Point count stations were sampled once during each of the eight seasons.

Surveys were conducted as extensive unlimited distance point counts as described by Ralph et al. (1995). Surveys were conducted from 0.25-h before sunrise to 4.5-h after sunrise when wind speed was less than 20 mph, air temperature above 0° C, and no more than light drizzle falling.

Species, which were flushed during approach to the point count stations, were included in the data for that station. Sampling duration per point count station was exactly 10-min. Samplers recorded each individual bird seen or heard while sampling at each station, with the exceptions of birds believed to have been recorded at a previous station, and also of flyovers. Data were recorded at each point count station on locational 'map' data sheets with concentric rings symbolizing incremental distances of 25m, 50m and beyond (see Figure 5). This data mapping allowed samplers to record individual birds and to keep tract of their movements so that double counting of individuals could be avoided. Samplers wore drab clothing and remained relatively quiet so as to avoid bias. A GPS unit was used to record and map point count locations, and locational data was rectified with base station data upon return to the lab.

Data Analysis

Unlimited distance data were used for seasonal summaries and descriptive statistics. Subsets of those data, those species detected within fifty meters of each point count station, were delineated for further statistical evaluation of both summer breeding season data sets. The strategy of using <50-m data for more extensive statistical analysis of forest habitat data is based on the recommendations of Ralph et al (1995).

It was decided that species richness data, categorized by habitat guild, were of main concern, as apposed to density, abundance or diversity indices. This decision was made based on four assumptions. First, it has been reported that densities for particular species are higher in smaller forest stands due to the ‘packing’ of territories, while in larger stands territories are more spread out. Thus, species density may not always be an indication of habitat quality (Kilgo et al 1998). More research is needed to establish the relationships between territorial size, fitness, landscape scale forest habitat metrics and habitat quality. Second, density indices are functions of species richness, numbers of individuals and unit area (Lancia et al 1996). This point count station based study does not attempt to quantify the unit area sampled. Third, abundance indices are intended to estimate population size, which is also beyond the scope of this study. Fourth, it is unknown whether an avian community that consists of species of various sizes, with territories of different sizes, and with different feeding requirements, 'should' have a diversity index that approaches unity.

Total avian species richness data (of species detected within fifty meters of each point count station) were correlated for both breeding seasons, using Spearman rank order correlation for non-parametric data, with the width of the riparian forest at each particular point count station.

As the patches are of various shapes, and there are also cuts through the forest (such as for railroad and power-line easements), guild species richness data for each point count station were also correlated with another metric; distance to the nearest edge.

Following habitat guild delineation (see Table 1), species richness data for each habitat guild delineated (forest interior, forest/edge, edge/shrub and riparian) were also correlated with forest width and distance to the nearest edge. Guild determination was adapted from breeding habitat requirements of detected species according to Ehrlich et al. (1988). Breeding status was based on breeding range maps from Stokes and Stokes (1996) and on the PIF database for 'Oaks and Prairies' physiographic area (#08). Neotropical migrants, including those species that breed locally, and those that use the Ray Roberts Greenbelt habitat for foraging during seasonal migration, were noted for all seasons.

Spatial Analysis

The two landscape scale forest metrics, width of the forest and distance to the nearest edge, were measured with ArcView measure tool via the Digital Orthophoto Quarter-Quad (DOQQ) data set (USGS Denton East and Green Valley quads), and geo-referenced with 1-meter resolution aerial photographs. Width of the riparian forest was measured with lines drawn at each point count station perpendicular to the river course. The placement of the river within each width was ignored.

Partners in Flight Indices

Priority Concern Scores that the National PIF has calculated for each species of breeding landbirds for each physiographic area, are intended to be used to prioritize habitat conservation efforts and maximize conservation efficiency. Habitat types with relatively high numbers of high priority avian species can be identified, and conservation resources can be used where they are most needed. Partners in Flight recommends that habitat distinctions within physiographic areas be kept fairly broad (Carter et al 1996). For example, the National PIF recognizes only three habitat types within the 'Osage Plains' area (#33); *grasslands, grass shrublands/savanna-woodlands,* and *riparian zones/wetland complexes* (Fitzgerald et al 2000). Texas PIF recognizes four habitat types each for its 'Oaks and Prairies' and 'Osage Plains' ecoregions, including *bottomland hardwood forest*s and *grasslands/shrublands*. This design of this study does not allow for a habitat comparison on this large a scale. The National PIF also recommends against secondary or tertiary habitat distinctions because of interpretation problems (Carter et al 1996).

One way to compare habitat types using priority concern scores is to calculate a mean average of priority concern scores for the avian species present in each habitat type during breeding season, and then to rank each habitat type by their mean scores. This method may overemphasize habitats with low species richness, or conversely, may underemphasize habitats with high species richness (Carter et al 1996).

Another habitat comparison index is calculated by summing the breeding species' priority concern scores, and ranking each habitat type by its summed scores. This may work well to distinguish between habitats with few low scored species and those with relatively more and higher scored species, but may underemphasize habitats with few but high scored species. In both indices described above, a species by species evaluation is advised, in order to avoid dropping high priority species from consideration (Carter et al 1996).

A third way to rank habitat types for conservation priority is to create avian species priority concern score rankings within each habitat type. The priority concern scores for each species present in a habitat would be ranked into categories, using the mean score as the dividing point between two of the ranks, and giving each category three or four species. This method would highlight the high priority species, and show how many high or moderately high priority species were present in each habitat type (Carter et al 1996).

These three methods could be used to compare habitat areas being considered for conservation, and the areas could be of similar or different habitat types. If similar habitat types were being compared, then a qualitative comparison of habitat quality could be explored based on species richness and priority species rankings.

Indices for the first two approaches will be calculated for combined 1999 and 2000 breeding season species lists for future reference. The combined species list will be ranked based on assigned priority concern scores for the (National PIF) 'Oaks and Prairies' physiographic area (#08) (last updated 1998), and divided into categories based on the recommendations of Carter (1996) and Hunter (personal communication, 2001). The results will be compared qualitatively with priority concern species lists for riparian and bottomland hardwood forests for the (Texas PIF) ‘Oaks and Prairies’ and ‘Osage Plains’ ecoregions, and with the overall Texas declining species priority list (Shackelford and Lockwood 2000). Also, the ranked categories will be examined in terms of habitat guilds and migration status.

Figure 5. Point count station data map sheet (Ralph et al 1995).

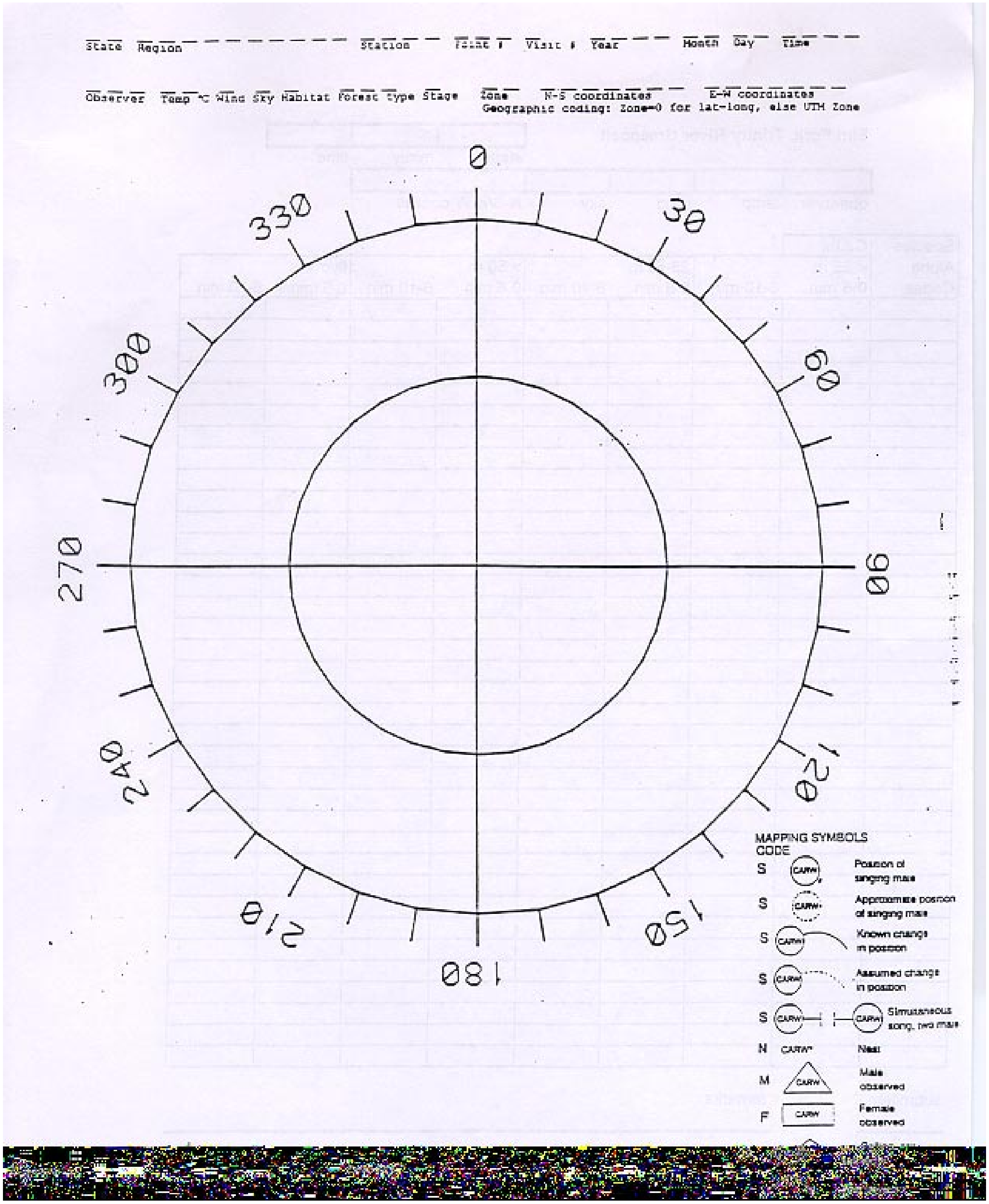


Table 1. Matrix of habitat guild and migratory status for breeding birds detected within 50-meters for combined 1999 and 2000 summer breeding seasons.

Species	Neotropical Migrants	Forest Interior	Forest/ Edge	Edge/ Shrub	Riparian
American Crow			*		
Belted Kingfisher					*
Blue-gray Gnatcatcher	*		*		
Brown-headed Cowbird			*		
Blue Jay			*		
Barred Owl		*			
Carolina Chickadee			*		
Carolina Wren				*	
Common Grackle			*		
Dicksissel	*			*	
Downy Woodpecker			*		
Eastern Bluebird				*	
Eastern-wood Pewee	*		*		
Eastern Phoebe			*		
Eastern-tufted Titmouse			*		
Great Blue Heron					*
Great-crested Flycatcher	*		*		
Great Egret				*	
Hairy Woodpecker		*			
Indigo Bunting	*			*	
Mockingbird				*	
Northern Cardinal			*		
Northern Parula	*	*			
Painted Bunting	*			*	
Pileated Woodpecker		*			
Prothonotary Warbler	*	*			
Red-bellied Woodpecker			*		
Red-eyed Vireo	*	*			
Red-shouldered Hawk		*			
Ruby-throated Hummingbird	*		*		
European Starling			*		
Summer Tanager	*	*			
Warbling Vireo			*		
White-eyed Vireo	*		*		
Wood Duck					*
Yellow-billed Cuckoo	*		*		

RESULTS

Summary Statistics

A total of 106 avian species were detected over the two-year study, with unlimited distance data, from each of the 62-point count stations (see Table 2). Thirty-six breeding species were recorded in the <50-m subset over the two summer breeding seasons. Seasonal summary statistics were calculated using unlimited distance data (see Table 3).

Fall 1998

Fifty-six avian species were recorded at point-count stations between the dates of 9/15 and 11/1. Of these species, the three most commonly encountered were American Crow at 55 stations (89%), Northern Cardinal at 51 stations (82%), and Carolina Chickadee at 50 stations (81%). These three species are year around residents of the North Texas area. The mean species per point count station for this seasonal survey was 9.73, while the median was 10. The minimum number of species recorded at any one station was 5, and the maximum number was 16. Standard deviation was 2.54.

Twelve species of Neotropical migrants (and two species of Neartic migrants) were detected within the fall migration season, and of these, six species, which do not breed in the North Texas area, were apparently utilizing the forest for foraging and or for shelter in their southerly passage. These species were, in order of number of occurrences, Brown Thrasher, Hermit Thrush, Brown Creeper, Traill's Flycatcher, Broad-winged Hawk, and Orange-crowned Warbler.

Winter 1999

Fifty-six species were detected during the winter resident season between the dates of 1/7 and 2/29. Similar to the previous fall, the three most commonly encountered species were Northern Cardinal at 57 stations (92%), American Crow at 53 stations (0.85%), and Carolina Chickadee at 52 stations (84%).

For this seasonal survey, the mean species richness was 9.15, the median 9, and the standard deviation 2.69. The minimum number of species recorded at a station was 3, and the maximum 15. Four species of Neotropical migrants and three species of Neartic migrants were seen or heard within this time period. These species were Brown Creeper, Brown Thrasher, Hermit Thrush, Northern Parula, White-eyed Vireo, Yellow-bellied Sapsucker, and Yellow-rumped Warbler.

Spring 1999

Sixty-three species were recorded during the spring migration season, from 4/07 to 6/14. Those species detected at the greatest number of point count stations were Northern Cardinal at 59 stations (98%), American Crow and Carolina Wren at 49 stations (79%). The maximum tally for species richness at a point-count station was 16, while the minimum was 7. Mean for this survey was 11.36, median was 11, and standard deviation was 2.17.

Twenty-nine species of Neotropical migrants were encountered during this time. Nine of these do not breed in the region, and so were apparently using the Greenbelt as a stopover while migrating north. These species were (in order of detection rate), Swainson's Thrush, Gray-cheeked Thrush, Nashville Warbler, Northern Oriole, Ovenbird, Rose-breasted Grosbeak, Canada Warbler, Tennessee Warbler, and Upland Sandpiper.

Summer 1999

Thirty-six species were recorded during the breeding season survey, between 6/18 and 7/3. As expected, the species encountered most frequently were Northern Cardinal at 61 stations (98%), Carolina Wren at 57 stations (92%), and both American Crow and Carolina Chickadee at 52 stations (84%). Species richness mean for this season was 9.82, while the median was 10. The minimum number of species found at a station was 6, and the maximum was 14. Standard deviation for these data is 2.06.

Twelve species of Neotropical migrants, all considered to be breeding residents, were detected during this time. Four of these species are forest interior breeders, and are as follows: Red-eyed Vireo at 25 stations (40%), Northern Parula at 12 stations (19%), Prothonotary Warbler at 5 stations (8%), and Summer Tanager 3 stations at (5%).

Five other forest interior breeding species were also detected during the '99 summer survey. These were (in order of detection frequency) Red-shouldered Hawk at 10 stations (16%), Pileated Woodpecker at 5 stations (8%), Barred Owl at 2 stations (3%) and both Hairy Woodpecker and White-breasted Nuthatch at 1 station each (2%).

One species not considered a breeder in the North Texas area, American Goldfinch, was recorded during this time at one station (2%).

Fall 1999

Fifty-four species were detected between the dates of 9/19 and 11/12, representing the '99 fall migration survey. American Crow was recorded most often, at 61 stations (98%), followed by both Carolina Wren and Red-bellied Woodpecker at 53 stations (85%). The mean for species richness was 8.45, the median 9, and the standard deviation 2.27. Minimum number of species at a point-count station was 4, while the maximum was 14.

Nine species of Neotropical migrants and two species of Neartic migrants were seen or heard during the survey, including five non-resident breeding species, in order of detection frequency: Traill's Flycatcher, Yellow-bellied Sapsucker, Nashville Warbler, Orange-crowned Warbler, and Winter Wren.

Winter 2000

Due to logistical problems, four point-count stations (40, 41,42, and 43) were not visited for sampling during this season. Sampling occurred between the dates of 2/8 and 3/16. 37 species were recorded at the remaining 58 stations. Northern Cardinal was found at all 58 stations, Carolina Wren at 54 stations (87%), and Eastern-tufted Titmouse at 50 stations (81%).

A mean of 8.55 was calculated for species richness data, and the median was established at 8. The maximum number of species at a station for this survey was 12; the minimum was 5, with a standard deviation of 1.76.

Two species of Neotropical migrants were detected; Great-crested Flycatcher and Rose-breasted Grosbeak, the former being considered a North Texas area breeder.

Spring 2000

Fifty-eight species were seen or heard between the dates of 3/29 and 5/30. The three most commonly detected species were Northern Cardinal at all 62 of the stations, Carolina Wren at 61 stations (98%), and Carolina Chickadee at 48 stations (77%).

Mean species richness for this season was 10.60, the median species number was 10.5, and the standard deviation was 2.31. Maximum species richness for any one station was 16, and the minimum was 6.

Twenty-one species of Neotropical migrants were encountered, including six species that do not breed in the area. These species were Nashville Warbler, Swainson's Thrush, Black-throated Green Warbler, Orange-crowned Warbler, Yellow-rumped Warbler, and Tennessee Warbler.

Summer 2000

Thirty-seven species were detected during the 2000 breeding season survey, between the dates of 6/2 and 6/21. Carolina Wren and Northern Cardinal were found at all 62 stations, while Carolina Chickadee were observed at 47 stations (76%).

The mean number of species found at point-count stations was 9.84, and the median number was 10, with a standard deviation of 2.06. Maximum species richness at a station was 15, and the minimum was 6.

Fourteen species of Neotropical migrants were recorded during this time, all of which are area breeders. Four of these species, considered forest interior breeders, were encountered as follows; Red-eyed Vireo at 22 stations (35%), Northern Parula at 18 stations (29%), Prothonotary Warbler at 12 stations (19%), and Summer Tanager at 2 stations (3%).

Four other species of forest interior breeders were also present during sampling sessions. They were Red-shouldered Hawk at 7 stations (7%), both Hairy and Pileated Woodpeckers at 5 stations (5%), and Barred Owl at 1 station (2%).

One species not considered an area breeder, Ruby-crowned Kinglet, was detected at one station during the breeding season.

Correlation Analysis

There was a moderate, significant correlation between forest interior species richness and width of the riparian forest for the 1999 summer breeding season (Spearman Rank Order $R=0.44$, $p<0.01$). There was also a significant but weak correlation between forest interior species richness and width of the riparian forest for the 2000 summer breeding season ($R=0.26$, $p=0.04$).

There were, respectively, moderate and weak significant correlations between forest interior species richness and distance to the nearest edge for the 1999-breeding season ($R=0.33$, $p<0.01$), and for the 2000-breeding season ($R=0.28$, $p=0.03$).

Edge shrub species richness and width of the riparian forest were negatively significantly correlated for the 1999-breeding season ($R= -0.36$, $p<0.01$). For the 2000 breeding season, total species richness and distance to the nearest edge were weakly correlated ($R=0.26$, $p=0.04$).

Partners in Flight Indices

All breeding species detected during the two summer seasons within 50m of the point count stations were assigned priority concern scores for the National Partners in Flight *Oaks and Prairies* physiographic region (#08). These scores were summed and the mean was determined. The sum of all scores was determined at 566, with a mean score of 15.7. These indices may be used in comparison with those calculated for other habitat types (as recognized by Partners in Flight) in the north central Texas area, provided that the limitations for such comparisons are kept in mind.

The species list was ranked in descending order by assigned priority concern scores. A midpoint of 16, based on the mean of summed scores above, was used to divide the species into two groups, namely *above* and *below average priority*. These groups were further divided into four and three categories, respectively, creating seven ranked categories containing from two to nine species each. The four highest ranked categories, which would be most important in the habitat prioritization process, contain only a few species each, as recommended by Carter et al (1996). As the groupings are somewhat arbitrary, and the lower ranked species are less important for the PIF process, the three lower ranked categories were allowed more species. Species with the same priority concern scores were always included in the same category (see Table 4).

Upon the recommendations of Hunter (personal communication, 2001), the two highest categorical divisions are *high* and *moderate priority*. *High priority* birds, those with priority concern scores over 21, include Painted Bunting and Yellow-billed Cuckoo. It is interesting that, in this study of forest bird community, the two highest priority species are edge/shrub and forest/edge species, respectively. Both of these species are Neotropical migrants. Texas Partners in Flight lists Painted Bunting as one of the eleven declining species of highest priority concern, showing declines in six out of nine state ecoregions. Yellow-billed Cuckoo is listed as being in decline in five out of nine Texas regions (Shackelford and Lockwood 2000)(see Table 5).

Moderate priority species, those with scores over 19, include Carolina Chickadee, Prothonotary Warbler, Dicksissel, Great-crested Flycatcher, and Summer Tanager. Only two of these, Prothonotary Warbler and Summer Tanager, are forest interior species. Dicksissel is an edge/shrub species, while Great-crested Flycatcher and Carolina

Chickadee are forest/edge species. The latter of these species is the only one that is not a Neotropical migrant.

Out of these two groups, only two species, Yellow-billed Cuckoo and Prothonotary Warbler, are included in the priority species lists for riparian or bottomland forests published by Texas PIF for the *Oaks and Prairies* or *Osage Plains* ecoregions (Shackelford and Lockwood 2000)(see Table 6). One other species included in these priority lists, Red-headed Woodpecker, was not detected in the study area during the sampled breeding seasons, and even though it was detected during non-breeding seasons and likely do breed in the area, they were not ranked.

Eight species were ranked *above average priority*. Of these, Northern Parula and Red-shouldered Hawk are forest interior species. Eastern-wood Pewee, Ruby-throated Hummingbird, White-eyed Vireo, Red-bellied Woodpecker, and Warbling Vireo are in the forest/edge habitat guild. Wood Duck is the only representative of the riparian guild in the *above average priority* group.

There are 22 species in the *below average priority* categories. Of these, four are forest interior species: Barred Owl, Hairy Woodpecker, Pileated Woodpecker and Red-eyed Vireo. The latter species is a Neotropical migrant.

There are two riparian species in the *below average priority* categories, Belted Kingfisher and Great Blue Heron, both year-around residents.

Eleven of the *below average priority* species are forest/edge birds. Two of these species, Blue-gray Gnatcatcher and Warbling Vireo, are Neotropical migrants.

Five edge/shrub species make up the remainder of the *below average priority* ranked species. The lowest of these is a Neotropical migrant: Indigo Bunting.

The National Partners in Flight *Conservation Plan* for the *Osage Plains* physiographic area (#33), which lies somewhat north and west of the study site, is not designed for true southeastern bottomland hardwood forests. Conservation strategies for the 'Osage Plains' (#33) riparian areas are primarily concerned with developing open canopied woodlands and or grassland-woodland mosaics. However, bottomland hardwood forest systems receive a brief mention in *the Riparian Zones and Wetland Complexes* section (Fitzgerald et al 2000). Of the four birds mentioned in this section, Prothonotary Warbler is the only species that was detected during the two-year study period.

Each recognized habitat type in the (National PIF) *Osage Plains* area (#33) is assigned a list of species considered to be in decline or on the increase (Fitzgerald et al 2000)(see Table 7). Three species found in the *above average priority* ranked category, Red-shouldered Hawk, White-eyed Vireo, and Ruby-throated Hummingbird, are considered to be increasing in number. Eastern Phoebe, Blue-gray Gnatcatcher, and Indigo Bunting, three species also considered to be increasing, were ranked in the *below average priority* categories.

Three species that were detected during the two-year study period are included in the National PIF *Osage Plains* (#33) declining list: Yellow-billed Cuckoo (ranked *high priority*), Eastern-wood Pewee (*above average priority*), and Hairy Woodpecker (*below average priority*). Three other species in the 'Osage Plains (#33) declining list, Red-headed Woodpecker, Yellow-breasted Chat, and Orchard Oriole, were detected only during non-breeding seasons, and so were not ranked in the Greenbelt breeding bird priority concern score list.

Table 2. Total species richness at unlimited distance, full two-year study combined. n=106

Alpha Code	Common Name	Alpha Code	Common Name	Alpha Code	Common Name
AMCR	American Crow	EATU	Eastern-tufted Titmouse	PROW	Prothonotary Warbler
AMGO	American Goldfinch	FISP	Field Sparrow	RBGR	Rose-breasted Grosbeak
AMKE	American Kestrel	FOSP	Fox Sparrow	RBWO	Red-bellied Woodpecker
AMRO	American Robin	FRGU	Franklin's Gull	RCKI	Ruby-crowned Kinglet
BASW	Barn Swallow	GBHE	Great Blue Heron	REVI	Red-eyed Vireo
BEKI	Belted Kingfisher	GCFL	Great-crested Flycatcher	RHWO	Red-headed Woodpecker
BEWR	Bewick's Wren	GCKI	Golden-crowned Kinglet	RODO	Rock Dove
BGGN	Blue-gray Gnatcatcher	GCTH	Gray-cheeked Thrush	RSHA	Red-shouldered Hawk
BGWA	Black-throated Green Warbler	GRCA	Gray Catbird	RSTO	Rufous-sided Towhee
BHCO	Brown-headed Cowbird	GREG	Great Egret	RTHA	Red-tailed Hawk
BLJA	Blue Jay	GTGR	Great-tailed Grackle	RTHU	Ruby-throated Hummingbird
BLVU	Black Vulture	HAWO	Hairy Woodpecker	RWBL	Red-winged Blackbird
BNHE	Black-crowned Night Heron	HETH	Hermit Thrush	SCFL	Scissor-tailed Flycatcher
BOBW	Bobwhite	HOFI	House Finch	SOSP	Song Sparrow
BRCR	Brown Creeper	HOSP	House Sparrow	STAR	European Starling
BROW	Barred Owl	HOWR	House Wren	SUTA	Summer Tanager
BRTH	Brown Thrasher	INBU	Indigo Bunting	SWTH	Swainson's Thrush
BWHA	Broad-winged Hawk	INDO	Inca Dove	TEWA	Tennessee Warbler
BWWA	Black-and-white Warbler	KILL	Killdeer	TRFL	Trail's Flycatcher
CACH	Carolina Chickadee	LISP	Lincoln's Sparrow	TUVU	Turkey Vulture
CAEG	Cattle Egret	LOSH	Loggerhead Shrike	UPSA	Upland Sandpiper
CAWA	Canada Warbler	MALL	Mallard	VESP	Vesper Sparrow
CAWR	Carolina Wren	MEAD	Eastern Meadowlark	WAVI	Warbling Vireo
CEWA	Cedar Waxwing	MOCK	Mockingbird	WBNU	White-breasted Nuthatch
CHSW	Chimney Swift	MODO	Morning Dove	WEVI	White-eyed Vireo
COGR	Common Grackle	NAWA	Nashville Warbler	WIWA	Wilson's Warbler
COHA	Cooper's Hawk	NOCA	Northern Cardinal	WIWR	Winter Wren
COYE	Common Yellowthroat	NOFL	Northern Flicker	WODU	Wood Duck
DCCO	Double-crested Cormorant	NOHA	Northern Harrier	WTSP	White-throated Sparrow
DEJU	Dark-eyed Junco	NOOR	Northern Oriol	YBCH	Yellow-breasted Chat
DICK	Dickcissel	NOPA	Northern Parula	YBCU	Yellow-billed Cuckoo
DOWO	Downy Woodpecker	OCWA	Orange-crowned Warbler	YBSA	Yellow-bellied Sapsucker
EABL	Eastern Bluebird	OROR	Orchard Oriol	YEWA	Yellow Warbler
EAKI	Eastern Kingbird	OVEN	Ovenbird	YRWA	Yellow-rumped Warbler
EAPE	Eastern-wood Pewee	PABU	Painted Bunting		
EAPH	Eastern Phoebe	PIWO	Pileated Woodpecker		

Table 3. Summary statistics for total species richness with unlimited distance and <50-meter PCS data (n=62), and forest distance metrics.

Unlimited Distance Data

Season	# Spp.	Mean	Std Err	Med	Min	Max	Std Dev
Fall '98	57	9.73	0.33	10	5	16	2.57
Winter '99	56	9.15	0.34	9	1	15	2.69
Spring '99	63	11.36	0.27	11	7	16	2.17
Summer '99	36	9.82	0.28	10	6	14	2.06
Fall '99	54	8.45	0.29	9	4	14	2.27
Winter '00	37	8.55	0.23	8	5	12	1.76
Spring '00	58	10.60	0.29	10.5	6	16	2.31
Summer '00	37	9.84	0.26	10	6	15	2.06

<50 Meter Data

Season	# Spp.	Mean	Std Err	Med	Min	Max	Std Dev
Summer '99	28	6.95	0.25	7.00	1.00	11.00	1.95
Summer '00	34	7.89	0.26	8.00	3.00	13.00	2.03

Forest Metrics (m)

Metrics	Mean	Std Err	Med	Min	Max	Std Dev
Forest Width	230.4	22.0	167.5	50.0	685.0	173.3
Distance to Nearest Edge	88.5	10.1	57.5	10.0	330.0	79.7

Table 4. Rankings and categories of PIF priority concern scores (with parameters) for the combined 1999 and 2000 breeding seasons. Summed scores=566, mean=15.7, and n=36.

Species	**RA**	**BD**	**ND**	**TN**	**TB**	**PT**	**AI**	**Score**	**Rating**
Painted Bunting	2	4	3	3	4	5	5	**26**	**HP**
Yellow-billed Cuckoo	3	1	2	3	3	5	5	**22**	**HP**
Carolina Chickadee	2	3	3	1	2	5	5	**21**	**MP**
Prothonotary Warbler	3	3	4	3	3	3	2	**21**	**MP**
Dicksissel	1	2	4	4	3	2	4	**20**	**MP**
Great-crested Flycatcher	2	1	3	3	3	5	3	**20**	**MP**
Summer Tanager	3	2	2	2	3	5	3	**20**	**MP**
Eastern-wood Pewee	3	1	2	3	3	4	3	**19**	AAP1
Ruby-throated Hummingbird	3	1	3	2	2	3	4	**18**	AAP1
White-eyed Vireo	2	2	4	2	3	2	3	**18**	AAP1
Wood Duck	3	1	2	3	3	3	3	**18**	AAP1
Northern Parula	2	2	4	2	2	3	2	**17**	AAP2
Red-bellied Woodpecker	2	2	3	2	1	2	4	**16**	AAP2
Red-shouldered Hawk	3	2	2	2	2	2	3	**16**	AAP2
Warbling Vireo	2	1	4	2	2	3	2	**16**	AAP2
~								**~**	
Belted Kingfisher	3	1	1	2	2	3	3	**15**	BAP1
Blue-gray Gnatcatcher	2	1	2	2	2	3	3	**15**	BAP1
Carolina Wren	2	2	2	2	2	2	3	**15**	BAP1
Mockingbird	1	1	1	1	1	5	5	**15**	BAP1
Brown-headed Cowbird	1	1	1	1	1	5	4	**14**	BAP2
Barred Owl	3	1	1	2	2	2	3	**14**	BAP2
Eastern Bluebird	2	1	2	2	2	1	4	**14**	BAP2
Eastern Phoebe	3	1	2	2	2	1	3	**14**	BAP2
Eastern-tufted Titmouse	2	2	2	1	1	2	4	**14**	BAP2
Hairy Woodpecker	3	1	1	2	2	3	2	**14**	BAP2
Pileated Woodpecker	3	1	1	2	2	3	2	**14**	BAP2
Red-eyed Vireo	1	2	2	2	2	3	2	**14**	BAP2
Downy Woodpecker	3	1	1	1	1	2	4	**13**	BAP3
Great Blue Heron	2	1	1	2	2	1	4	**13**	BAP3
Blue Jay	2	1	2	1	1	2	3	**12**	BAP3
Great Egret	2	1	1	2	2	2	2	**12**	BAP3
Indigo Bunting	1	1	3	2	1	2	2	**12**	BAP3
Northern Cardinal	1	1	1	1	1	2	5	**12**	BAP3
American Crow	1	1	1	1	1	1	5	**11**	BAP3
Common Grackle	1	1	2	1	1	2	3	**11**	BAP3
European Starling	1	1	1	1	1	2	3	**10**	BAP3

RA=relative abundance
BD=breeding distribution
ND=non-breeding distribution
TN=threats to non-breeding
TB=threats to breeding
PT=population trend
AI=area importance
HP=high priority
MP=moderate priority
AAP=above average priority
BAP=below average priority

Table 5. Texas PIF statewide species priority list, with number of regions (out of nine) in which species are in decline (Shackelford and Lockwood 2000).

Bell's Vireo	**9**
Scissor-tailed Flycatcher*	**8**
Cassin's Sparrow	**6**
Painted Bunting**	**6**
Yellow-billed Cuckoo**	**5**
Mountain Plover	**5**
Scaled Quail	**5**
Swainson's Hawk	**5**
Least Tern	**5**
Black-capped Vireo	**4**
Northern Bobwhite	**4**

*detected during two year study
**detected <50m during breeding season(s)

Table 6. Texas PIF priority bird lists for Oaks and Prairies and Osage Plains ecoregions: riparian and bottomland hardwood forests (Shackelford and Lockwood 2000).

Osage Plains	**Oaks and Prairies**
Red-headed Woodpecker	Yellow-billed Cuckoo
Prothonotary Warbler	Swainson's Warbler
Mississippi Kite	Worm-eating Warbler
Baltimore Oriole	Swallow-tailed Kite
Black-chinned Hummingbird	
Yellow-billed Cuckoo	

Table 7. Avian increases and declines in National PIF Osage Plains physiographic area (#33): riparian woodlands habitat (Fitzgerald et al 2000).

Increasing	**Declining**
Red-shouldered Hawk**	Green Heron
Eastern Phoebe**	Black-billed Cuckoo
White-eyed Vireo**	Yellow-billed Cuckoo**
Cliff Swallow	Red-headed Woodpecker*
Blue-gray Gnatcatcher**	Hairy Woodpecker**
Indigo Bunting**	Eastern-wood Pewee**
Ruby-throated Hummingbird**	Bell's Vireo
	Yellow-breasted Chat*
	Orchard Oriole*
	Baltimore Oriole
	Black-capped Chickadee
	Bullock's Oriole

*detected during study
**detected <50 m during breeding season(s)

DISCUSSION

Correlation Analysis

Several studies have reported positive correlations between total species richness and riparian zone width (Darveau et al 1995, Thurmand et al 1995, Kilgo et al 1998), as well as to forest area (Blake and Karr 1987). This study did not confirm that trend.

One might expect to find those species requiring forest interior habitat for breeding requirements to be found more often in wider areas of riparian forest than in more narrow areas during the breeding season (Kilgo et al, 1998). Indeed, this was the pattern that emerged for both the 1999 and the 2000 breeding seasons (see Figures 6 and 7). On the scatter plots for these correlations, lines of best fit were drawn to clarify the common trend. Second order polynomial lines were chosen, because the 'thresholds' indicated might be helpful in formulating criteria for management decisions. Both of the second order polynomial lines suggest riparian forest width thresholds of about 450 m, or about 200m on either side of the river, for a diverse forest interior species community.

Significant correlations of forest interior species richness and distance to the nearest edge indicate that this parameter must also be considered in forest management. The scatter plots for these data sets were also fitted with second order polynomial lines to help estimate thresholds (see Figures 8 and 9). These lines of best fit both indicate that species richness for forest interior birds 'peaks' at about 200-m distance from the nearest edge, suggesting that patches at least 400m in diameter are needed for maintaining a diverse forest interior avian community.

The weak negative correlation between edge/shrub species for the 1999 breeding season is not surprising. Logically, one would expect to find fewer of these species in wider forest tracts. However, the presence of edge/shrub species in even the widest forest areas (about 700m) may indicate that none of the patches are large enough to provide true forest interior conditions. On the other hand, these species may simply make use of canopy openings in these patches as ‘edge’ habitat. A linear line of best fit was drawn on the scatter plot of these data, since no suggestion of a threshold was desired in this instance (see Figure 10).

It is unclear why total species richness would correlate significantly with distance to the nearest edge for the 2000 summer breeding season (see Figure 11), when there was no significant correlation between total species richness and forest width for the two years tested. The positive relationship may be due to a few outliers in the data toward the upper end of the x-axis, but may reflect the positive relationship between total species richness and forest area as reported by Blake and Karr (1987).

Partners in Flight Index Analysis

Upon first examination, the priority concern score rankings of the 2-year study breeding bird list may seem somewhat counter intuitive. For example, a few species that might be considered important to ecosystem function, such as top predators like Barred Owls and cavity nest excavators like Pileated Woodpeckers, are ranked in the *below average priorit*y categories. Hairy Woodpeckers, considered in decline by the National PIF, are likewise ranked *below average priority*. Also, it appears illogical that the above species should be ranked equally with a pest species such as Brown-headed Cowbird. However, the PIF prioritization process does not attempt to prioritize species on the basis of ‘ecological importance’ per se (there is no parameter for *eco-system services*), and the priority concern scores should not be interpreted as if it does.

Certain logical patterns do emerge from the ranked breeding bird list. Six of the seven species ranked *high* or *moderate priority* are Neotropical migrants. High *area importance* scores (>3) often contribute to the high overall priority scores for these species. One exception to this trend is Prothonotary Warbler, which has a high *non-breeding distribution* score. The other exceptions, Great-crested Flycatcher and Summer Tanager, both have high scores in *population trend*. The highest ranked year around resident species, Carolina Chickadee (ranked *moderate priority*), has high parameter scores for *population trend* and *area importance*.

Only three of the *below average priority* species are Neotropical migrants. All 'pest' species on the list, Brown-headed Cowbirds, Common Grackles, American Crows, and Blue Jays, are ranked in the *below average priority* categories. These species are widespread habitat generalists who have benefited from urbanization and habitat fragmentation (Ehrlich et al 1988). This trend reveals a general lack of threat to this group, and does not represent the threats they themselves pose to other species.

Figure 6. Scatterplot and associated threshold of the relationship between forest interior species richness (<50-m) and width of the riparian forest during the 1999 summer breeding season.

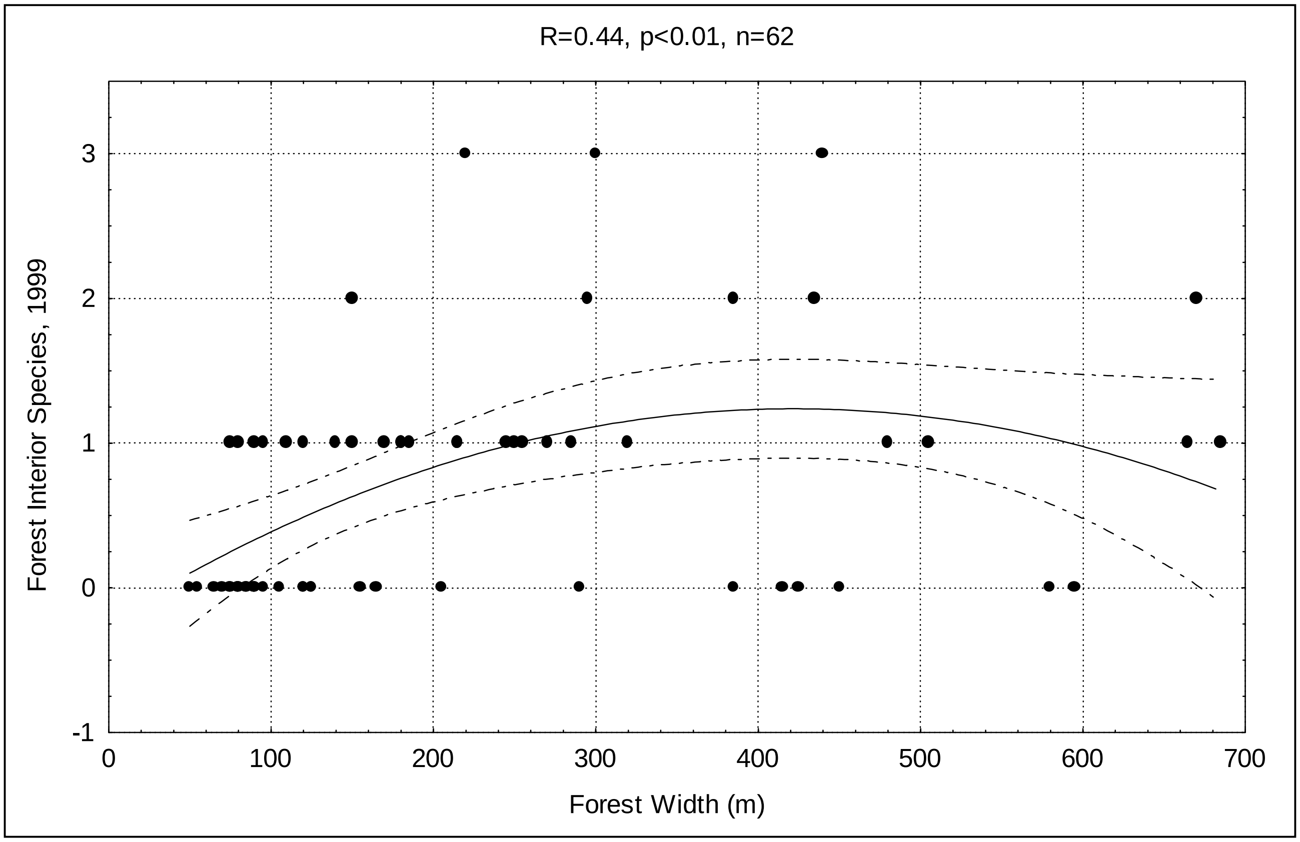


Figure 7. Scatterplot and associated threshold of the relationship between forest interior species richness (<50-m) and width of the riparian forest during the 2000 summer breeding season.

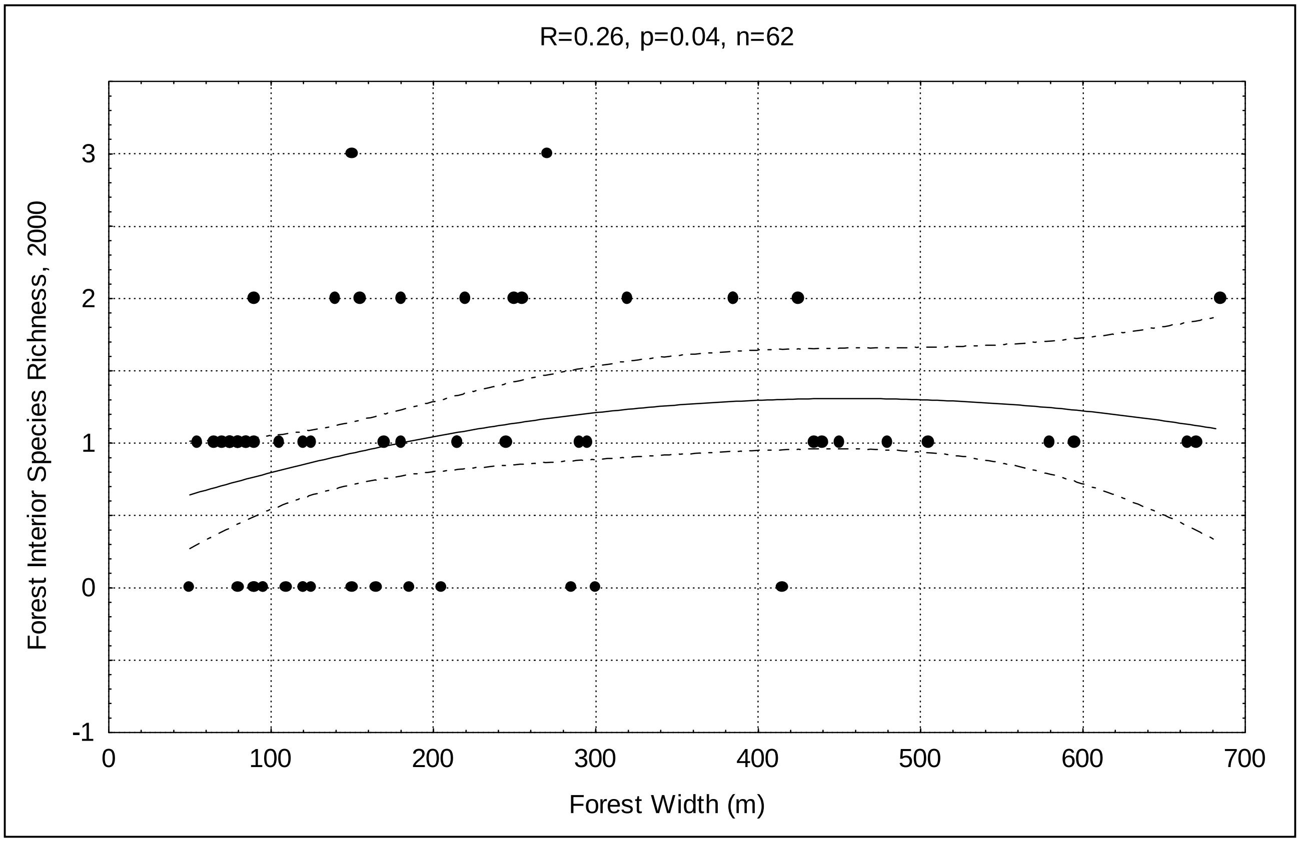


Figure 8. Scatterplot and associated threshold of the relationship between forest interior species richness (<50-m) and distance to the nearest edge during the 1999 summer breeding season.

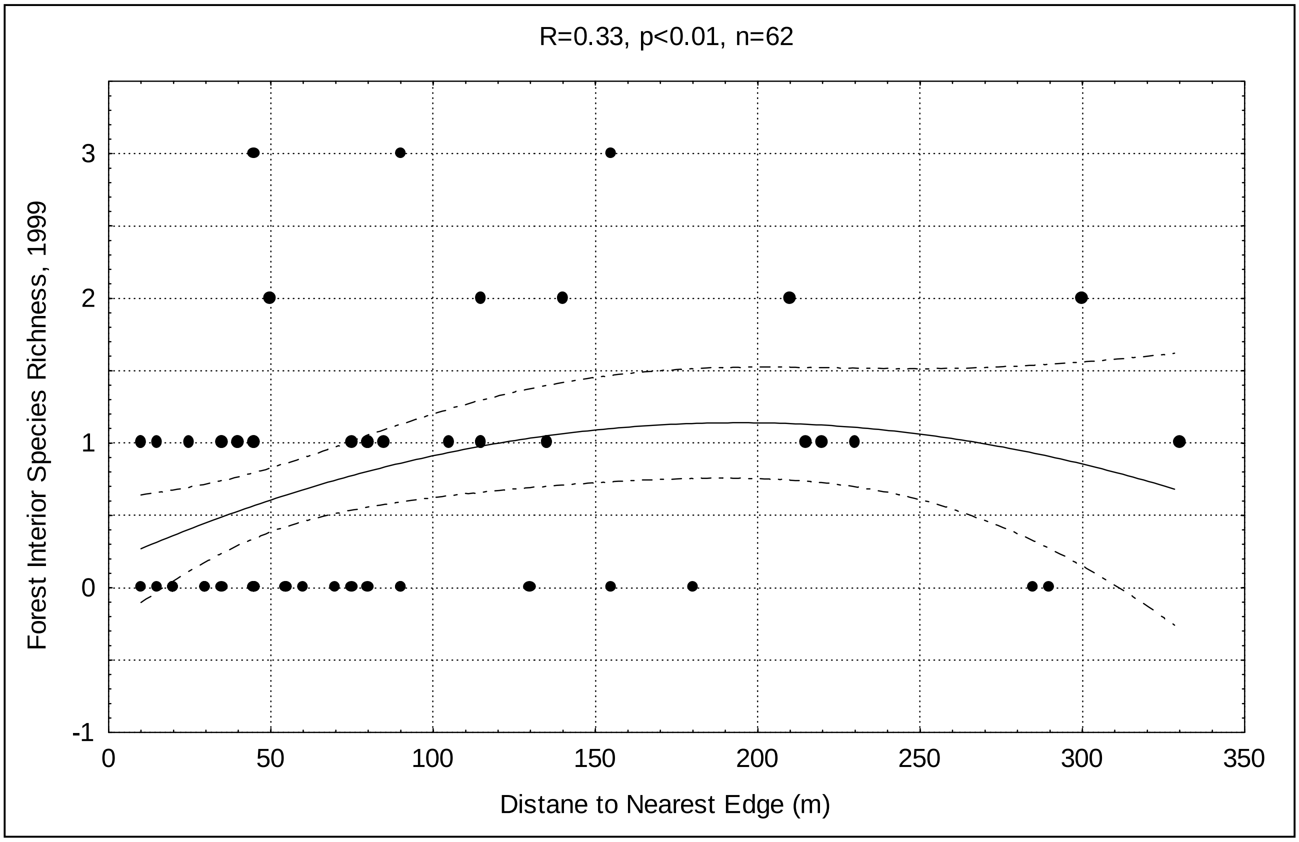


Figure 9. Scatterplot and associated threshold of the relationship between forest interior species richness (<50-m) and distance to the nearest edge during the 2000 summer breeding season.

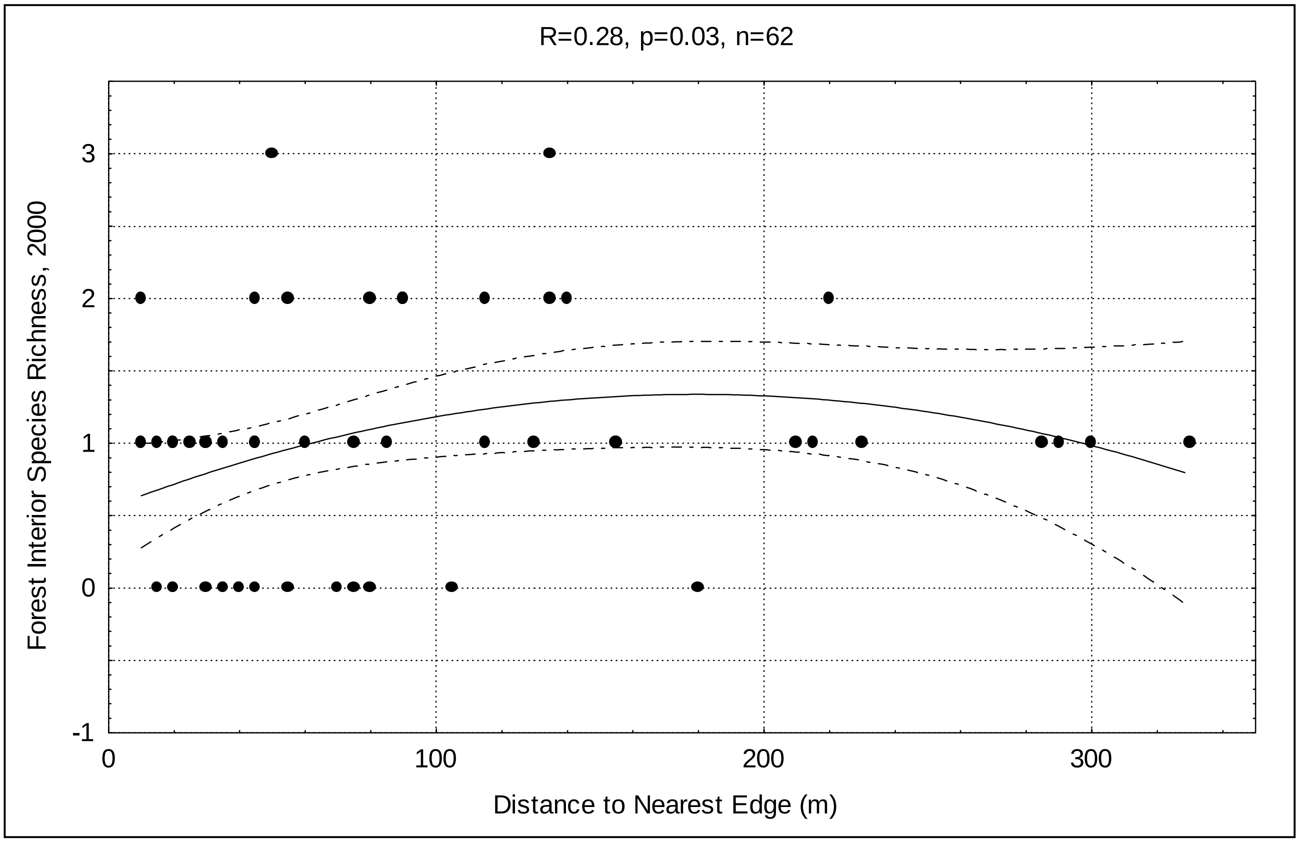


Figure 10. Scatterplot of the relationship between edge/shrub species richness (<50-m) and width of the riparian forest during the 1999 summer breeding season.

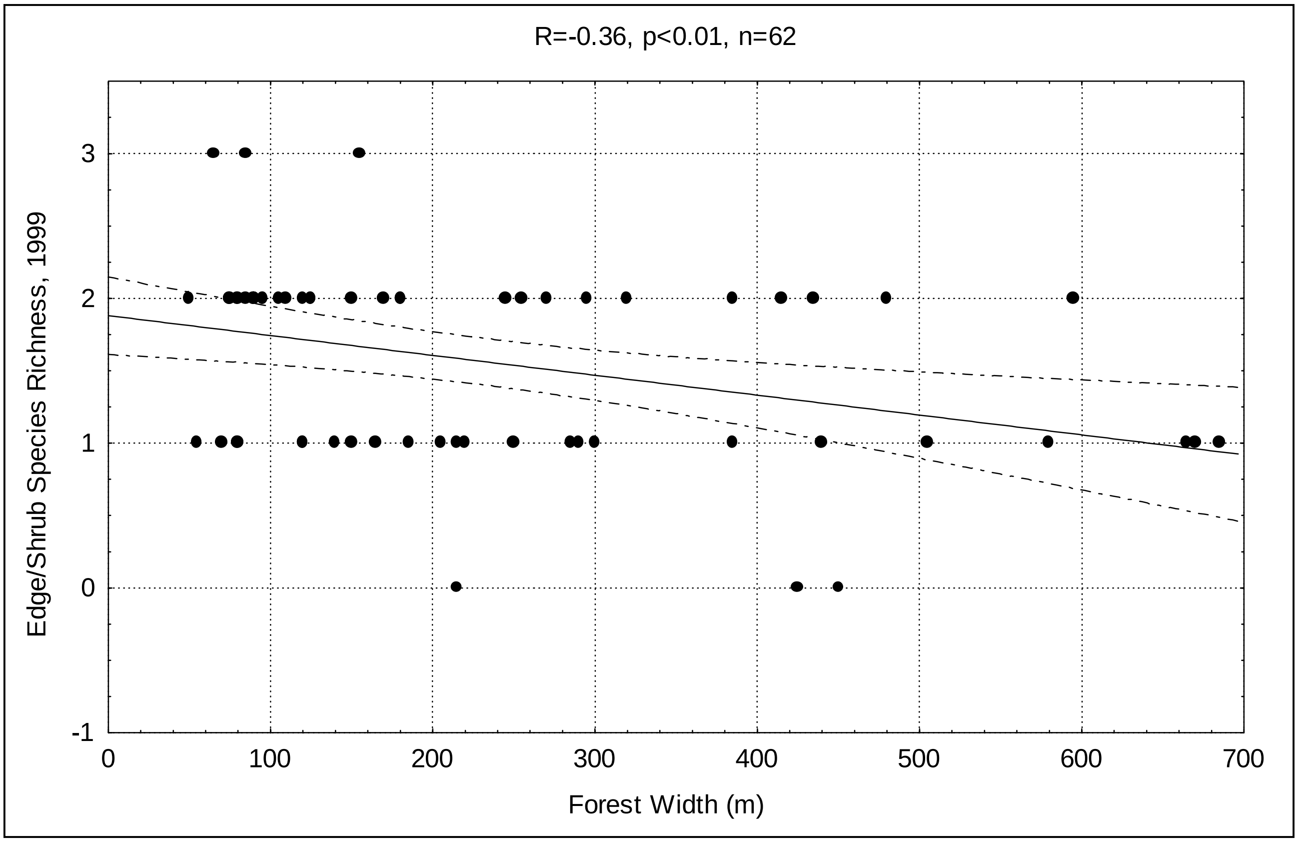
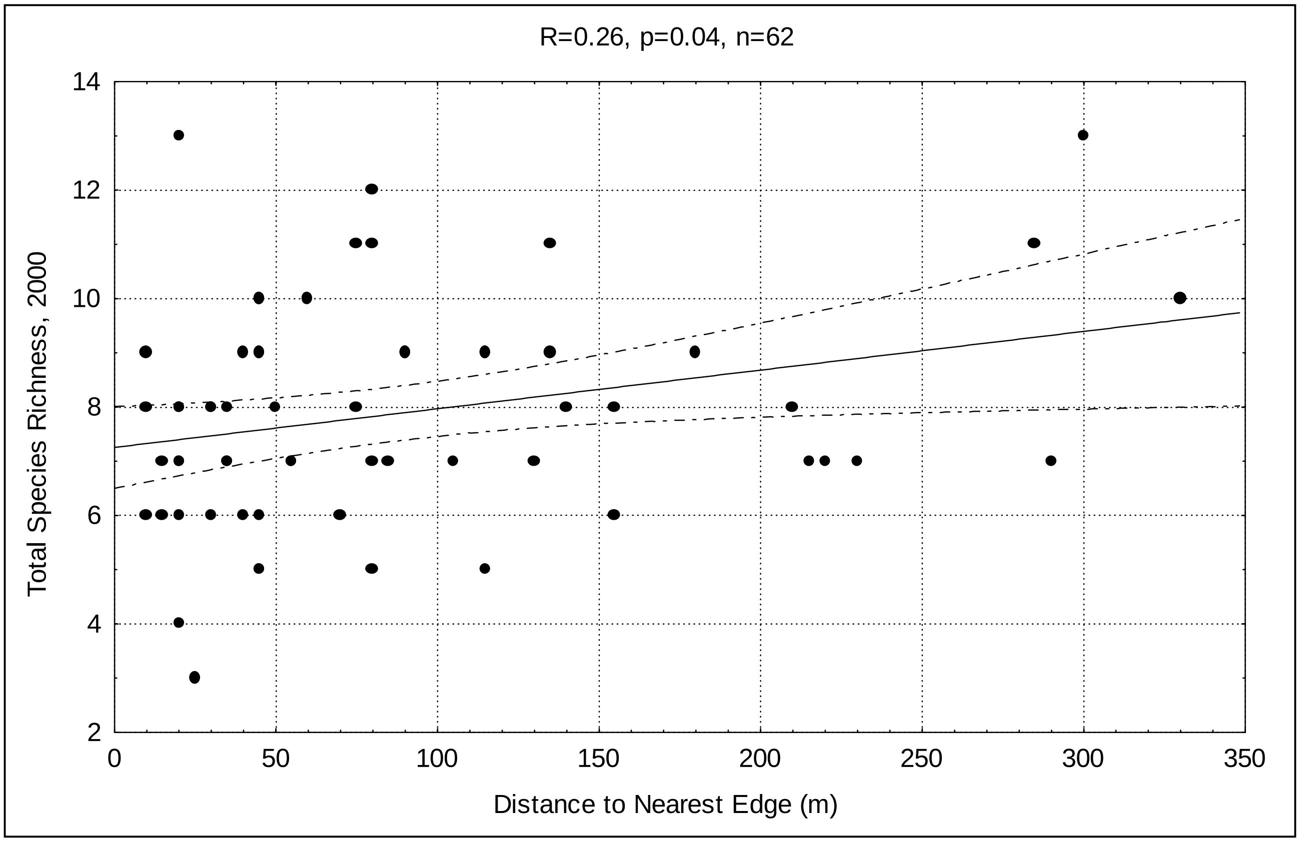


Figure 11. Scatterplot of the relationship between total species richness (<50-m) and distance to the nearest edge during the 2000 summer breeding season.



CONCLUSIONS

This study was designed to sample the forest breeding-bird population in the Ray Roberts Greenbelt, and to correlate these data with the spatial metrics of the forest at each point where avian data was collected. This strategy allows thresholds relating to forest interior species richness and riparian forest width to be established.

The breeding-bird species list was also used to construct a habitat priority index, using Partners in Flight priority concern scores to rank the species detected during the 1999 and 2000 summer seasons. This index, which could be used to compare the bottomland hardwood forest habitat of the Ray Roberts Greenbelt with other habitat types in the region for conservation priority, was examined with regard to habitat guilds and migration status.

Together, these two approaches to analyzing the breeding bird species richness data may be helpful in establishing criteria for management of the Greenbelt and of other similar riparian forests, especially southeastern bottomland hardwood systems.

Correlation Analysis

The positive correlations between forest interior avian species with both landscape metrics over the two breeding seasons support the concept that species richness for this guild increases with forest width and patch size. Management of riparian forest with a goal of conserving these species by increasing riparian forest width and patch size would also increase the amount of available habitat for forest/edge guild members. These species are apparently as successful in wider forest areas (in terms of species richness) as in more narrow areas. This point is important, because land managers should know if management decisions aimed at benefiting one habitat guild (i.e. forest interior) would be detrimental to another guild (i.e. forest/edge).

The riparian habitat guild, represented by only three species, appears to be independent of forest width. However, Wood Ducks and Great Blue Herons both nest in trees, (snags in the case of Wood Ducks and canopy height tree tops in the case of Great Blue Herons), and Belted Kingfishers use tree branches to perch when hunting fish (Ehrlich et al 1988).

A management strategy designed to increase forest width and patch size in the Ray Roberts Greenbelt would (eventually) reduce habitat area for edge/shrub species, of which some, like the Painted Bunting, are Neotropical migrants considered to be in decline.

However, the study area in question is primarily floodplain, and was likely a widespread bottomland hardwood forest in pre-settlement times. Management of bottomlands with the intent of restoring the riparian forest that once covered them is ecologically sound land management (Mannen et al 1996). If managers were to decide to prioritize an increase in the area of forest habitat within the Greenbelt, then local (upland) grassland/shrubland areas could be considered for restoration and conservation to mitigate any eventual edge/shrub habitat losses.

Natural succession of oldfield to early forest, even if aided by proactive restoration projects, would actually increase the amount of edge/shrub habitat for a number of decades. This temporary (in the context of plant community succession) increase of edge/shrub habitat could benefit species such as Painted Bunting for a considerable period of time.

Based on the correlation analysis discussed, a minimum riparian forest width of 400-m, and a patch diameter of 400-m is recommended as a primary goal. (See Figure 12 for a visual graphic of present forest coverage of the Ray Roberts Greenbelt and the additional forest coverage based on the 400-m minimum width recommendation.) The projected forest coverage was produced by creating a 200-m buffer, which follows the river course within the study area, thereby projecting 200-m of forest coverage on either bank. The width of the river itself was ignored. The floodplain of the Elm Fork Trinity River, as defined by FEMA, is also shown, demonstrating the conservative nature of the proposed 400-m minimum forest width as compared to the probable extent of the riparian forest in pre-settlement times. While actual forest boundaries would have fluctuated in response to cycles of precipitation, drought, and fire, it is likely that the entire floodplain was forested most of the time. The area of the current forest (572 hect, 1413 ac) and the proposed buffer combined is 891 hect (2202 ac), while the approximate area of the floodplain (minus the tributary extensions) is 2226 hect (5500 ac). Thus, even with the addition of 320 hect (792 ac) of forest buffer to the present forest coverage (i.e., planting the un-forested portion of the buffer), the combined total would only represent about 40% of the probable historic forest extent. This estimate ignores the changes in the contour of the floodplain at the northern end of the study area, where the Ray Roberts dam was built. The floodplain would doubtless have been wider there, increasing the proportion of cleared floodplain to forest coverage. There is also a small amount of patchy, highly fragmented forest coverage (associated with tributaries) within the floodplain and not included in the contiguous riparian forest coverage, which was ignored in calculations (see Figure 4).

Habitat managers might find it necessary to shift the 50:50 proportion of the forest buffer on either side of the river depending on issues such as river and forest stand configuration, erosion control, water quality control, and cost efficiency. However, it is clear that the banks of the river should have some amount of forest coverage for erosion control.

Management toward the minimum goal of 400-m riparian forest width would likely involve decisions involving burning and mowing practices, edge management, forest succession and restoration. This type of management would be appropriate for southeastern bottomland hardwood forest systems that have been subject to extensive fragmentation. Also, the prioritization of bottomland forest restoration to increase forest width may be justified more easily where the primary land-use in the surrounding area involves clear cutting for pasture, agriculture or silviculture.

The 400-m minimum width for riparian forest recommended here is twice as large as that recommended by Barry (2000) for the Ray Roberts Greenbelt. His 200-m threshold is based on forest interior species richness and abundance data collected in *corridor* point count stations, and is an average of thresholds found by the 2nd order polynomial line of best-fit method (as described above) and an upper quartile data method. Barry (2000) did not calculate width thresholds for *patch* data, or for *overall width* gradient data (as was done in this data analysis). His 200-m threshold is intended for short (250-m maximum) connective corridors only, and not for width of the riparian forest in general.

Land managers of bottomland hardwood forests may consider conducting breeding bird surveys to characterize their local forest avian community, in order to integrate these data with their approach to forest width and patch size management. Using data collection techniques and analysis methods described in this paper would allow managers of riparian and especially southeastern bottomland hardwood forest systems to customize their management criteria to regional conditions, rather than relying on ‘rules of thumb’.

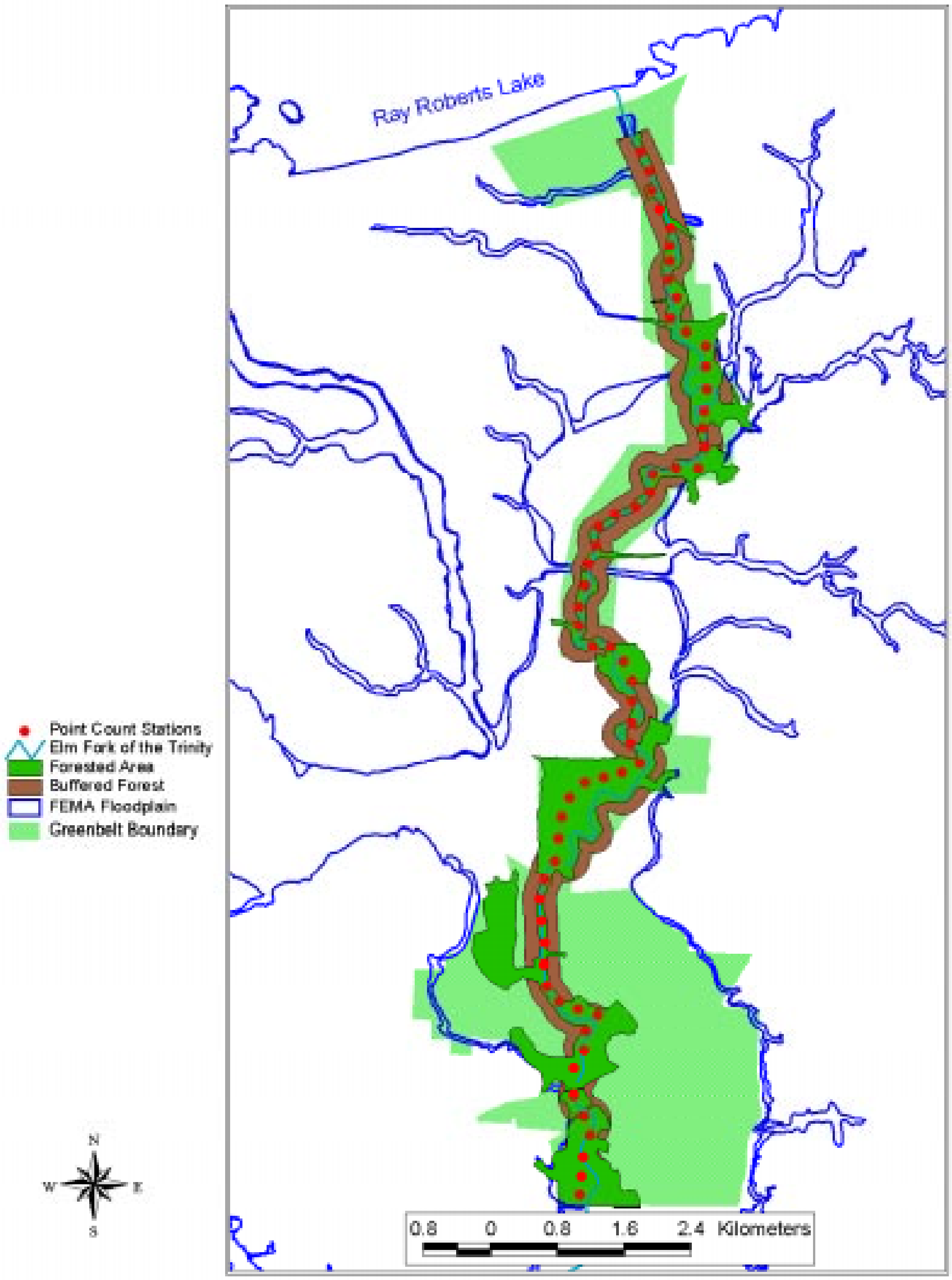
Partners in Flight Analysis

The Partners in Flight habitat prioritization process promises to be a useful tool for directing conservation resources efficiently. The inconsistencies between National PIF *physiographic regions* and Texas PIF *ecoregions* probably reflect the difficulties in delineating landscape scale ecosystems into separate bioregions, especially (as in this case) when political boundaries and ecological ‘transition zones’ are involved (Shackelford and Lockwood 2000). That no *Bird Conservation Plan* exists as of yet for the (National PIF) *Oaks and Prairies* (#08) physiographic area is due to the fact that this physiographic region was actually delineated by the North American Bird Conservation Initiative and adopted by PIF (Fitzgerald 2001, personal correspondence).

When using the PIF habitat prioritization process to compare habitat types, it is important to consider habitat guilds of detected species. This particular study, which was designed to examine the relationships between landscape scale forest metrics and habitat guilds, and sampled a forest of greatly varying widths, created a species list including many edge specialists. It is therefore not surprising that an edge/shrub species such as Painted Bunting was detected. The fact that this species has the highest PIF ranking of all breeding birds detected is perhaps ecologically ironic, but not especially problematic. In fact, this species was detected in some of the wider forest areas during both breeding seasons sampled. To minimize this type of complication in comparing PIF recognized habitat types for prioritization, sampling design could avoid point count station proximity to transitional ecotones (such as the forest edge) as much as possible. This strategy might provide more ‘pure’ habitat guild species richness lists for habitat comparisons. As PIF habitat type categories are broad, and do not necessarily mesh with avian habitat guild divisions, species lists from any one PIF habitat type are likely to contain representatives of more than one habitat guild. One should recognize that a few of the *below average priority* forest interior species, such as Barred Owls and Pileated Woodpeckers, might be considered *ecologically important*, in the sense that they are valuable for forest ecosystem function.

Without an alternative habitat index for comparison, this study cannot rank the priority status of the Ray Roberts Greenbelt for avian conservation. However, based on the PIF recommended management guidelines for riparian and bottomland hardwood forests, management of the Greenbelt should be steered toward forest succession, aided when possible by restoration efforts. Fitzgerald et al (2000) wrote in the Bird Conservation plan for the (National PIF) *Osage Plains* physiographic area, that “ . . .conservation efforts along rivers and other riparian corridors should seek to develop extensive and contiguous tracts of habitat that mimic pre-settlement conditions and seek to restore natural communities . . . “. Conservation and enhancement of the Ray Roberts Greenbelt forest would ensure breeding habitat and foraging for a diverse avian forest community, including forest interior species, forest/edge and riparian species, Neotropical migrants, raptors, and woodpeckers, for generations to come.

Figure 12. ArcView image of the Ray Roberts Greenbelt.



LITERATURE CITED

Barry, D. 2000. Thresholds in avian communities at multiple scales: relationships between birds, forests, habitats, and landscape in the Ray Roberts Greenbelt, Denton, Texas. Ph. D. Dissertation. University of North Texas, Denton, Texas.

Carter, M. F., W. C. Hunter, D. N. Pashley, J. S. Bradley, J. Price, and G. S. Butcher. 1996. Setting Landbird conservation priorities for states and physiographic regions within the United States. PIF prioritization database. Unpublished document.

Carter, M. F., W. C. Hunter, D. N. Pashley, K. V. Rosenberg. 2000. Setting conservation priorities for landbirds in the United States: the Partners in Flight approach. The Auk 117(2):541-548.

Colorado Bird Observatory PIF Database. 2000. www.cbobirds.org/pif/. Accessed 12/18/2000.

Ehrlich, P. R., D. S. Dobkin, and D. Wheye. 1988. The Birder's Handbook; A Field Guide to the Natural History of North American Birds. Simon and Schuster, Inc. New York, New York.

Fitzgerald, J., B. Busby, M. Howery, R. Klataske, D. Reinking, D. Pashely. 2000. Partners in Flight bird conservation plan for the Osage Plains physiographic area 33. Version 1.0.

Fitzgerald, J. 2001. Personal correspondence. January 2001.

Haegen, W. M. V. and R. M. DeGraaf. 1996. Predation on artificial nests in forested riparian buffer strips. Journal of Wildlife Management 60(3): 1996.

Hagar, J. C. 1999. Influence of riparian buffer width on bird assemblages in western Oregon. Journal of Wildlife Management 63(2): 484-496.

Hodges, M. F. Jr. and D. G. Krementz. 1996. Neotropical migratory breeding bird communities in riparian forests of different widths along the Altamaha River, Georgia. Wilson Bulletin 108(3): 496-506.

Hunter, W. C. 2001. Personal correspondence. January 2001.

Keller, C. M. E., C. S. Robbins, and J. S. Hatfield. 1993. Avian communities in riparian forests of different widths in Maryland and Delaware. Wetlands Vol. 13, No. 2, Special Issue: 137-144. June 1993.

Kilgo, J. C., R. A. Sargent, B. R. Chapman, and K. V. Miller. 1998. Effect of stand width and adjacent habitat on breeding bird communities in bottomland hardwoods. Journal of Wildlife Management 62(1): 72-83.

Kinley, T. A. and N. J. Newhouse. 1997. Relationship of riparian zone width to bird density and diversity in southeastern British Columbia. Northwest Science Vol. 71, No.2, 1997.

Lancia, R, A., J. D. Nichols, and K. H. Pollock. 1996. Estimating the number of animals in wildlife populations. Research and management techniques for wildlife and habitats. Ed. by T. A. Bookhout. The Wildlife Society, Inc. 1996.

Leahy, C. 1982. The Birdwatcher's Companion. Random House. New York, New York.

Mannan, R. W., R. N. Conner, B. Marcot, and J. M. Peek. 1996. Managing forestlands for wildlife. Research and management techniques for wildlife and habitats. Ed. by T.A. Bookhout. The Wildlife Society, Inc. 1996.

Partners in Flight – U.S. Homepage. 2000. www.partnersinflight.org/pif/. Accessed 12/18/2000.

Ralph, C. J., S. Droege, and J.R. Sauer. 1995. Managing and monitoring birds using point counts: standards and applications. Monitoring bird populations by point counts. Ed. by C. J. Ralph, J. R. Sauer, and S. Droege. Pacific Southwest Research Station, Forest Service, US Dept. of Agriculture. 1997.

Robbins, C. S., D. K. Dawson, B. A. Dowell. 1989. Habitat requirements of breeding forest birds of the Middle Atlantic States. Wildlife Monographs 103:1-34.

Shackelford, C. E. and M. W. Lockwood. 2000. Rare and declining birds of Texas: conservation needed. Second Edition. Texas Partners in Flight in the Wildlife Diversity Branch, and the Natural Resources Program. Texas Parks and Wildlife.

Stokes, D., and L. Stokes. 1996. Stokes Field Guide to Birds: Eastern Region. Little, Brown and Company. USA.

Thurmond, D. P., K. V. Miller, T. G. Harris. 1995. Effect of streamside management zone width on avifauna communities. Southern Journal of Applied Forestry 19(4): 166-169.

Whitaker, D. M. and W. A. Montevecci. 1999. Breeding bird assemblages inhabiting riparian buffer strips in Newfoundland, Canada. Journal of Wildlife Management 63(1): 167-179.

APPENDICES

Appendix 1. Point count stations with associated distance metrics and UTM coordinates.

	Forest	Distance	UTM Coordinates			Forest	Distance	UTM Coordinates	
PCS	**Width**	**to Edge**	**West**	**North**	**PCS**	**Width**	**to Edge**	**West**	**North**
1	95	40	682928	3692044	**32**	435	210	682726	3685930
2	50	15	683032	3691807	**33**	215	25	682820	3685696
3	125	75	683061	3691564	**34**	110	35	682823	3685450
4	75	10	683154	3691367	**35**	120	60	682827	3685207
5	85	30	683291	3691141	**36**	90	35	682809	3684954
6	155	55	683274	3690921	**37**	220	90	682922	3684715
7	180	80	683277	3690731	**38**	415	180	682703	3684602
8	125	45	683259	3690508	**39**	505	215	682490	3684542
9	245	115	683362	3690279	**40**	595	285	682257	3684482
10	165	70	683289	3690033	**41**	665	330	682072	3684296
11	255	115	683468	3689868	**42**	580	290	681985	3684057
12	285	105	683708	3689720	**43**	480	230	681945	3683824
13	295	115	683712	3689473	**44**	385	90	681898	3683545
14	320	135	683715	3689188	**45**	85	45	681779	3683319
15	290	130	683690	3688926	**46**	65	30	681714	3683080
16	90	10	683671	3688716	**47**	80	45	681739	3682814
17	80	10	683704	3688503	**48**	55	20	681772	3682548
18	205	80	683615	3688260	**49**	120	35	681764	3682298
19	170	75	683353	3688261	**50**	105	45	681797	3682046
20	180	85	683068	3688189	**51**	140	45	681953	3681859
21	75	15	683043	3687964	**52**	270	135	682176	3681763
22	80	20	682865	3687781	**53**	250	80	682416	3681696
23	70	20	682617	3687692	**54**	300	45	682271	3681505
24	75	20	682422	3687549	**55**	385	140	682246	3681261
25	90	30	682393	3687306	**56**	440	155	682123	3681043
26	80	20	682296	3687082	**57**	150	50	682128	3680733
27	185	80	682263	3686837	**58**	215	45	682252	3680485
28	120	55	682188	3686604	**59**	425	90	682318	3680252
29	90	20	682191	3686364	**60**	450	155	682239	3679991
30	95	20	682352	3686118	**61**	670	300	682216	3679757
31	150	40	682570	3686112	**62**	685	220	682199	3679522

Appendix 2. Seasonal species richness at unlimited distance.

Fall 1998

American Crow	Great-crested Flycatcher
American Goldfinch	Golden-crowned Kinglet
American Kestrel	Great-tailed Grackle
American Robin	Hairy Woodpecker
Barn Swallow	Hermit Thrush
Belted Kingfisher	House Wren
Blue-gray Gnatcatcher	Killdeer
Brown-headed Cowbird	Loggerhead Shrike
Blue Jay	Meadowlark
Brown Creeper	Northern Cardinal
Barred Owl	Northern Flicker
Brown Thrasher	Orange-crowned Warbler
Broad-winged Hawk	Pileated Woodpecker
Carolina Chickadee	Ring-billed Gull
Carolina Wren	Red-bellied Woodpecker
Common Grackle	Ruby-crowned Kinglet
Double-crested Cormorant	Red-headed Woodpecker
Dark-eyed Junco	Red-shouldered Hawk
Dickcissel	Rufous-sided Towhee
Downy Woodpecker	Red-tail Hawk
Eastern Bluebird	Red-winged Blackbird
Eastern Kingbird	Scissor-tailed Flycatcher
Eastern Wood Pewee	Song Sparrow
Eastern Phoebe	Traill's Flycatcher
Eastern-tufted Titmouse	Turkey Vulture
European Starling	White-eyed Vireo
Fox Sparrow	Winter Wren
Great Blue Heron	White-throated Sparrow

n=56

Winter 1999

American Crow	Hairy Woodpecker
American Goldfinch	Hermit Thrush
American Robin	House Finch
Belted Kingfisher	Killdeer
Bewick's Wren	Loggerhad Shrike
Brown-headed Cowbird	Mallard
Blue Jay	Meadowlark
Black Vulture	Morning Dove
Brown Creeper	Northern Cardinal
Barred Owl	Northern Flicker
Brown Thrasher	Northern Harrier
Carolina Chickadee	Parula Warbler
Carolina Wren	Pileated Woodpecker
Cedar Waxwing	Ring-billed Gull
Common Grackle	Red-bellied Woodpecker
Cooper's Hawk	Ruby-crowned Kinglet
Double-crested Cormorant	Rock Dove
Dark-eyed Junco	Red-shouldered Hawk
Downy Woodpecker	Red-tailed Hawk
Eastern Bluebird	Red-winged Blackbird
Eastern Phoebe	Song Sparrow
Eastern-tufted Titmouse	Turkey Vulture
European Starling	White-eyed Vireo
Fox Sparrow	Winter Wren
Great Blue Heron	Wood Duck
Golden-crowned Kinglet	White-throated Sparrow
Great Egret	Yellow-bellied Sapsucker
Great-tailed Grackle	Yellow-rumped Warbler

n=56

Appendix 2 (cont).

Spring 1999

American Crow	Lincoln's Sparrow
American Goldfinch	Mourning Dove
Barn Swallow	Nashville Warbler
Belted Kingfisher	Northern Cardinal
Blue-gray Gnatcatcher	Northern Oriole
Brown-headed Cowbird	Orchard Oriole
Blue Jay	Ovenbird
Black Vulture	Painted Bunting
Barred Owl	Parula Warbler
Carolina Chickadee	Pileated Woodpecker
Cattle Egret	Prothonotary Warbler
Canada Warbler	Rose-breasted Grosbeak
Carolina Wren	Red-bellied Woodpecker
Cedar Waxwing	Red-eyed Vireo
Chimney Swift	Red-headed Woodpecker
Common Grackle	Red-shouldered Hawk
Common Yellowthroat	Ruby-throated Hummingbird
Dickcissel	Red-winged Blackbird
Downy Woodpecker	Scissor-tailed Flycatcher
Eastern Kingbird	Summer Tanager
Eastern Phoebe	Swainson's Thrush
Eastern-tufted Titmouse	Tennesee Warbler
Franklin's Gull	Turkey Vulture
Great Blue Heron	Upland Sandpiper
Great-crested Flycatcher	Warbling Vireo
Gray-cheeked Thrush	White-eyed Vireo
Gray Catbird	Wood Duck
Great Egret	White-throated Sparrow
Hairy Woodpecker	Yellow-breasted Chat
House Wren	Yellow-billed Cuckoo
Indigo Bunting	Yellow Warbler
Inca Dove	**n=63**

Summer 1999

American Crow
Belted Kingfisher
Blue-gray Gnatcatcher
Brown-headed Cowbird
Blue Jay
Barred Owl
Carolina Chickadee
Cattle Egret
Carolina Wren
Common Grackle
Downy Woodpecker
Eastern Bluebird
Eastern Wood Peewee
Eastern Phoebe
Eastern-tufted Titmouse
Great Blue Heron
Great-crested Flycatcher
Great Egret
Great-tailed Grackle
Hairy Woodpecker
Indigo Bunting
Killdeer
Northern Cardinal
Northern Parula
Painted Bunting
Pileated Woodpecker
Prothonotary Warbler
Red-bellied Woodpecker
Red-eyed Vireo
Red-shouldered Hawk
Red-tailed Hawk
Red-winged Blackbird
Summer Tanager
White-breasted Nuthatch
White-eyed Vireo
Yellow-billed Cuckoo

n=36

Appendix 2 (cont).

Fall 1999

American Crow	Great-tailed Grackle
American Goldfinch	Hairy Woodpecker
American Kestral	Hermit Thrush
American Robin	House Finch
Barn Swallow	House Sparrow
Belted Kingfisher	Indigo Bunting
Blue-gray Gnatcatcher	Killdeer
Brown-headed Cowbird	Loggerhead Shrike
Blue Jay	Eastern Meadowlark
Bobwhite	Nashville Warbler
Brown Creeper	Northern Cardinal
Barred Owl	Northern Flicker
Brown Thrasher	Orange-crowned Warbler
Black-and-white Warbler	Pileated Woodpecker
Carolina Chickadee	Red-bellied Woodpecker
Carolina Wren	Ruby-crowned Kinglet
Common Grackle	Red-headed Woodpecker
Cooper's Hawk	Red-shouldered Hawk
Dark-eyed Junco	Ruby-throated Hummingbird
Downy Woodpecker	Song Sparrow
Eastern Bluebird	Traill's Flycatcher
Eastern Phoebe	White-eyed Vireo
Eastern-tufted Titmouse	Wilson's Warbler
European Starling	Winter Wren
Great-blue Heron	Wood Duck
Golden-crowned Kinglet	White-throated Sparrow
Gray Catbird	Yellow-bellied Sapsucker

n=54

Winter 2000

American Crow
American Robin
Belted Kingfisher
Brown-headed Cowbird
Blue Jay
Black Vulture
Barred Owl
Carolina Chickadee
Carolina Wren
Common Grackle
Downy Woodpecker
Eastern Bluebird
Eastern Wood Pewee
Eastern Phoebe
Eastren-tufted Titmouse
Great Blue Heron
Great-crested Flycatcher
Great-tailed Grackle
Hairy Woodpecker
Killdeer
Meadowlark
Morning Dove
Northern Cardinal
Northern Flicker
Pileated Woodpecker
Ruby-breasted Grosbeak
Red-bellied Woodpecker
Ruby-crowned Kinglet
Red-shouldered Hawk
Red-tailed Hawk
Red-winged Blackbird
Song Sparrow
European Starling
Turkey Vulture
Wood Duck
White-throated Sparrow

n=37

Appendix 2 (cont).

Spring 2000

American Crow	Loggerhead Shrike
American Goldfinch	Mourning Dove
Belted Kingfisher	Nashville Warbler
Blue-gray Gnatcatcher	Northern Cardinal
Black-throated Green Warbler	Northern Flicker
Brown-headed Cowbird	Northern Parula
Blue Jay	Orange-crowned Warbler
Black-crowned Night Heron	Painted Bunting
Barred Owl	Pileated Woodpecker
Brown Thrasher	Prothonotary Warbler
Carolina Chickadee	Red-bellied Woodpecker
Carolina Wren	Ruby-crowned Kinglet
Cedar Waxwing	Red-eyed Vireo
Common Grackle	Red-shouldered Hawk
Dickcissel	Red-tailed Hawk
Downy Woodpecker	Red-winged Blackbird
Eastern Kingbird	Scissor-tailed Flycatcher
Eastern Phoebe	Song Sparrow
Eastern-tufted Titmouse	Summer Tanager
European Starling	Swainson's Thrush
Field Sparrow	Tennesee Warbler
Great Blue Heron	Turkey Vulture
Great-crested Flycatcher	Vesper Sparrow
Gray Catbird	White-eyed Vireo
Great-tailed Grackle	Wood Duck
Hairy Woodpecker	White-throated Sparrow
Indigo Bunting	Yellow-billed Cuckoo
Killdeer	Yellow Warbler
Lincoln's Sparrow	Yellow-rumped Warbler

n=58

Summer 2000

American Crow
Blue-gray Gnatcatcher
Brown-headed Cowbird
Blue Jay
Barred Owl
Carolina Chickadee
Carolina Wren
Dicksissel
Downy Woodpecker
Eastern Bluebird
Eastern Wood Pewee
Eastern Phoebe
Eastern-tufted Titmouse
European Starling
Great Blue Heron
Great-crested Flycatcher
Great Egret
Hairy Woodpecker
Indigo Bunting
Killdeer
Mockingbird
Mourning Dove
Northern Cardinal
Northern Parula
Painted Bunting
Pileated Woodpecker
Prothonotary Warbler
Red-bellied Woodpecker
Ruby-crowned Kinglet
Red-eyed Vireo
Red-shouldered Hawk
Ruby-throated Hummingbird
Summer Tanager
Warbling Vireo
White-eyed Vireo
Wood Duck
Yellow-billed Cuckoo

n=37

Appendix 3. Species richness at <50-meters for 1999 and 2000 summer breeding seasons.

Summer 1999
American Crow
Belted Kingfisher
Blue-gray Gnatcatcher
Brown-headed Cowbird
Blue Jay
Barred Owl
Carolina Chickadee
Carolina Wren
Common Grackle
Downy Woodpecker
Eastern Wood Pewee
Eastern Phoebe
Eastern-tufted Titmouse
Great Blue Heron
Great-crested Flycatcher
Great Egret
Hairy Woodpecker
Indigo Bunting
Northern Cardinal
Northern Parula
Painted Bunting
Pileated Woodpecker
Prothonotary Warbler
Red-bellied Woodpecker
Red-eyed Vireo
Red-shouldered Hawk
White-eyed Vireo
Yellow-billed Cuckoo

n=28

Summer 2000
American Crow
Blue-gray Gnatcatcher
Brown-headed Cowbird
Blue Jay
Carolina Chickadee
Carolina Wren
Dicksissel
Downy Woodpecker
Eastern Bluebird
Eastern Wood Pewee
Eastern Phoebe
Eastern-tufted Titmouse
Great Blue Heron
Great-crested Flycatcher
Great Egret
Hairy Woodpecker
Indigo Bunting
Mockingbird
Northern Cardinal
Northern Parula
Painted Bunting
Pileated Woodpecker
Prothonotary Warbler
Red-bellied Woodpecker
Ruby-crowned Kinglet
Red-eyed Vireo
Red-shouldered Hawk
Ruby-throated Hummingbird
European Starling
Summer Tanager
Warbling Vireo
White-eyed Vireo
Wood Duck
Yellow-billed Cuckoo

n=34

Great Trinity Forest Management Plan

Wildlife Management

Breeding Bird Abundance in Bottomland Hardwood Forests: Habitat, Edge and Patch Size Effects

The Condor 102:748–758

BREEDING BIRD ABUNDANCE IN BOTTOMLAND HARDWOOD FORESTS: HABITAT, EDGE, AND PATCH SIZE EFFECTS[1]

REX SALLABANKS,[2] JEFFREY R. WALTERS[3] AND JAIME A. COLLAZO
Department of Zoology, North Carolina State University, Box 7617, Raleigh, NC 27695

Abstract. We studied breeding bird communities in extensive bottomland hardwood forests along the lower Roanoke River in North Carolina during 1992 and 1993. We documented a rich avian community and recorded exceptionally high densities of two species (Prothonotary Warbler *Protonotaria citrea*, Acadian Flycatcher *Empidonax virescens*), as well as modest densities of three species rarely encountered elsewhere in the region (Cerulean Warbler *Dendroica cerulea*, Swainson's Warbler *Limnothlypis swainsonii*, American Redstart *Setophaga ruticilla*). The effects of patch size and edge on bird abundance were small in this forested landscape, but forest type had a large effect. We found half of the species analyzed to differ in abundance between the two primary habitat types, swamp forest and levee forest. In contrast, no species was consistently more abundant at patch interiors than near edges, and only two forest birds were more common in large compared with small patches. Species analyzed included permanent residents, short-distance migrants, Neotropical migrants, and those identified as forest-interior and area-sensitive species in other studies. Our results suggest that the Roanoke River bottomland forests may be functioning effectively as a reserve for a number of bird species.

Key words: bottomland forests, edge, habitat, landscape, patch size, point counts.

INTRODUCTION

Bottomland hardwood forests of the southeastern United States are critical breeding areas for many Neotropical migrants (Wharton et al. 1981, Hodges and Krementz 1996). Within the United States, bottomland hardwoods are being lost perhaps five times faster than any other major hardwood forest type (Abernathy and Turner 1987) and represent the wetland system with most rapidly diminishing acreage (Turner et al. 1981). Loss and alteration primarily takes the form of clearing and draining for crop production and, less frequently, conversion to forest plantations for timber production. These uses result in habitat fragmentation and degradation, as well as habitat loss, causing major impacts on breeding bird communities (Mitchell and Lancia 1990, Mitchell et al. 1991, Pashley and Barrow 1992). Changes in hydrology due to flood control are another common agent of habitat change in these systems.

Bottomland forests are particularly vulnerable to habitat fragmentation because they often occur as relatively narrow linear bands along rivers. The effects of habitat fragmentation and degradation on animal and plant populations have become an increasingly important concern in recent years (Schwartz 1997 and references therein). Of particular concern is the role of forest fragmentation in the decline of some migratory bird populations (Askins et al. 1990, Faaborg et al. 1995). As forests become more fragmented, the proportion of forest habitat near edges increases geometrically, creating edge effects (Harris 1988), ecological traps (Gates and Gysel 1978), and population sinks (Pulliam 1988, Donovan et al. 1995). In the eastern United States, birds near edges and in small fragments suffer from elevated rates of nest predation and of brood parasitism by the Brown-headed Cowbird, *Molothrus ater* (Brittingham and Temple 1983, Andrén and Angelstam 1988, Hoover et al. 1995). The magnitude of edge and patch size effects may depend on the extent of fragmentation in the regional landscape (Robinson et al. 1995, Faaborg et al. 1998, Hartley and Hunter 1998).

In this paper we report on breeding bird abundance in the most extensive bottomland hardwood forests remaining in the mid-Atlantic region, located on the lower Roanoke River in eastern North Carolina. The forested floodplain along the lower Roanoke ranges up to 8 km across and contains an estimated 60,000 ha of

[1] Received 14 July 1999. Accepted 12 July 2000.
[2] Current address: Sustainable Ecosystems Institute, 30 East Franklin Road, Suite 50, Meridian, ID 83642.
[3] Corresponding author and current address: Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061.

contiguous bottomland and swamp forest communities. Over 220 species of birds have been recorded in the floodplain, including at least 90 breeding residents and 40 breeding Neotropical migrants; this represents the highest breeding bird diversity known in the North Carolina Coastal Plain. Some Neotropical migrants breeding along the Roanoke (e.g., Cerulean Warbler *Dendroica cerulea* and Swainson's Warbler *Limnothlypis swainsonii*) are of special concern in North Carolina and elsewhere because of their declining numbers and restricted ranges (Lee and Parnell 1990). We studied the two primary natural communities in the Roanoke floodplain: cypress-gum swamp forest (brownwater subtype) and coastal plain levee forest (brownwater subtype) (Schafale and Weakley 1990).

Our primary objective was to determine the abundance and habitat relationships of breeding bird species, particularly Neotropical migrants, in order to assess the conservation value of the Roanoke bottomlands to birds. In 1989, the U.S. Fish and Wildlife Service acquired 13,000 ha of bottomland forest along the Roanoke to create the Roanoke River National Wildlife Refuge. An additional 5,500 ha are under state jurisdiction, and The Nature Conservancy, timber companies, and private individuals also retain significant holdings. Information about conservation values is needed to make informed decisions about management of current holdings and acquisition of additional land.

Our secondary objective was to document effects of proximity to edge and patch size on bird abundance within the natural mosaic of habitat patches in the Roanoke system. This serves two purposes. First, it provides a baseline against which effects of human-induced fragmentation, both within the Roanoke system and in other, similar systems, can be measured. Second, it contributes to the accumulation of a data set on variation in effects of patchiness and landscape structure on bird abundance across systems, which is critical to understanding effects of fragmentation (Walters 1998). Most studies on the effects of habitat fragmentation have examined woodlots that have become isolated because of agricultural and/or urban encroachment (Walters 1998). Contrast between habitat types in these landscapes is great, and edges are external, non-natural, abrupt, and permanent (Saurez et al. 1997). In our study area, patches of one forest type are linked by relatively undisturbed forest of a second type, rather than by cleared agricultural or urban land. Using the terminology of Saurez et al. (1997), the edges we examined are external, natural ones that are either gradual with modest contrast between habitat types (swamp-levee boundaries) or abrupt with high contrast (river-levee edges).

METHODS

STUDY AREA

In 1992 and 1993, we studied breeding bird communities of swamp and levee forest along a 150-km portion of the lower Roanoke River in eastern North Carolina, from Halifax to near the river's mouth at Plymouth. The swamp forest occurs in backswamps, sloughs, and other areas that in most years are flooded much of the growing season. Dominant tree species are water tupelo (*Nyssa aquatica*) and bald-cypress (*Taxodium distichum*), with Carolina ash (*Fraxinus caroliniana*) as a common midstory tree species. The levee forest occurs at higher elevations than swamp forest, on natural levees adjacent to the river channel. The levee forest canopy is dominated by a mixture of bottomland hardwoods such as sycamore (*Platanus occidentalis*), American elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), sugarberry (*Celtis laevigata*), boxelder (*Acer negundo*), water hickory (*Carya aquatica*), and sweetgum (*Liquidambar styraciflua*). Midstory tree species include pawpaw (*Asimina triloba*) and ironwood (*Carpinus caroliniana*), and vines are an abundant and conspicuous component of the community.

There is little change in canopy height and overstory tree density in the transition from swamp to levee. Forests are mature second growth, with canopy height of about 30 m (mean = 32 m, range among study plots 26–41 m). In some swamp forest, mature bald-cypress have been removed by selective logging. There is sharp contrast in plant community composition between swamp and levee, and swamp forest contains much lower densities of understory plants and shrubs, and somewhat lower densities of midstory trees. The ecotone between levee and swamp is not as abrupt as between levee and river or swamp and agricultural field, but typically it extends only a few meters.

The Roanoke bottomlands contain 13 other plant community types besides swamp forest

FIGURE 1. Satellite photograph of Roanoke River, North Carolina floodplain showing five types of transects sampled for relative breeding abundance. Lighter patches adjacent to river are levee forest and dark patches are swamp forest. White patches are agricultural fields surrounding the bottomland forests. Transects indicated are (1) narrow levee interior, (2) wide levee interior, (3) small swamp interior, (4) large swamp interior, and (5) large swamp edge.

and levee forest, but these other communities are restricted in their distribution, for example to slopes, to areas near the mouth of the river, or to special locations such as beaver ponds. The upland habitat matrix surrounding the bottomland communities consists mostly of cropland and pastureland on higher terraces of the floodplain that flood rarely or not at all (Fig. 1). Fields tend to be large, although they are usually broken up by wind breaks, drainage ditches, and other shrubby cover.

ASSESSMENT OF BIRD COMMUNITIES

In order to determine the effects of habitat type, interior versus edge location, and patch size on bird communities, we established 35 permanent transects in levee and swamp forest tracts (primary transects). We placed 14 transects in the center of levee patches of varying width (150–1,500 m wide), and 14 in the center of swamp forest patches of varying size (12–2,500 ha). We placed the remaining seven transects within 50 m of the edge of the seven largest swamp patches (340–2,500 ha) (Fig. 1). Each habitat patch contained one transect, with the exception of large swamp patches which contained two transects (an interior transect and an edge transect). We assumed all transects to be independent samples because they were always at least 1 km apart.

We censused birds on four other levee transects that were not included in the above design. These transects were located in levee forest that contained substantial thickets of giant cane (*Arundinaria gigantea*) (cane transects). They were censused to determine associations between bird species and this unique habitat component, but were not included in statistical analyses.

We used the fixed-radius point count censusing technique (Hutto et al. 1986) to survey breeding bird communities in 1992 and 1993. Each transect was 300 m long, had three count stations at 0, 150, and 300 m, and was visited three times during the period 1 May–10 July in each year. We made counts at each count station for 10 min between sunrise (approximately 06:00) and 10:00. At each count, we identified all vocal and visual detections to species and recorded their distance as < 30 m or > 30 m.

We examined edge effects by comparing breeding bird abundances between locations relatively far from patch edges and locations relatively close to patch edges. For levee forest this was a comparison between wide (650–1,500 m) and narrow (150–300 m) levees; for swamp forest this was a comparison between large swamp interiors and large swamp edges. Narrow levees were impacted by two edges each (river-levee, swamp-levee) that were 75–150 m from the census point depending on the width of the levee (Fig. 1). Large swamp edges were impacted by one edge (swamp-levee) that was 50 m from the census point.

We examined patch size effects by regressing breeding bird abundance against the size of habitat patches. Because levee forest occurs more as a linear habitat than as discrete patches, we regressed abundance against levee width to assess effects of levee patch size. For swamp forest, we used data from interiors of large (340–2,500 ha) and small (12–128 ha) patches (Fig. 1) to regress abundance against patch size.

STATISTICAL ANALYSIS

To avoid including birds that were outside the habitat/patch of interest, we only used detections within the 30-m radius in our analyses. We used ANOVA to examine relationships between the relative abundance of species and habitat type and transect location relative to edge. Model terms were year (1992 or 1993), habitat (levee or swamp forest), location [habitat] (swamp interior or edge, narrow or wide levee), year $\times$ habitat, and year $\times$ location [habitat]. The models' response variables were the mean number of detections of a particular species per transect per year. Mean number of detections was obtained by first averaging the three visits to a count station within a year, and then averaging the three count station means within a transect. Census data were power transformed to meet homogeneity of variance assumptions (Levene's test, $P > 0.05$) (Levene 1960). To assess the possibility that lack of independence of data collected from the same transect in consecutive years affected our results, we repeated the analyses using year as a repeated measure. Excluding year effects, results were identical using either approach, or analyzing only a single year's data.

For the regression analyses examining effects of patch size, we combined data from 1992 and 1993 except where *t*-tests (swamp forest) or ANOVA results (levee forest, see above) indicated a year effect. The response variable again was the mean number of detections per point count within a transect for each species. Data from levees were again power transformed, but this transformation was not necessary for data from swamp forest.

In addition to the above species-specific analyses, we also regressed average number of individuals and species against patch size for swamps and against forest width for levees. For these analyses we used the mean number of individuals and species detected per point count within a transect obtained by pooling all detections.

We used JMP software (JMP 1994) to perform statistical analyses.

RESULTS

We recorded 69 species of birds during morning censuses; 29 (42%) were Neotropical migrants (long-distance migrants), 4 (6%) were short-distance migrants, 5 (7%) were coastal migrants, and 31 (45%) were permanent residents. We recorded 24 of these 69 species 10 or more times within the 35 primary transects. We recorded four other species, White-eyed Vireo (*Vireo griseus*), Kentucky Warbler (*Oporornis formosus*), Swainson's Warbler, and Hooded Warbler (*Wilsonia citrina*), 10 or more times if the four additional cane transects are included. Each of these species was strongly associated with cane. The remaining 41 species included 10 waterbirds, 4 passage migrants, 3 species that soared above the forest, 7 species associated with agricultural lands, and 17 rare forest species. Notable among the latter were Cerulean Warbler, found only on upstream levee transects, Scarlet

TABLE 1. Results of ANOVA examining relationship of relative abundance of each individual species to habitat type (levee vs. swamp forest) [habitat], transect location (wide vs. narrow levee, swamp edge vs. interior) (location [habitat]), year (1992 vs. 1993) [year], habitat-year interaction (habitat × year), and location-year interaction (location × year) in bottomland forest along the Roanoke River, North Carolina. Entries are P-values for the indicated F-test, with significant ($P < 0.05$) and marginally significant ($0.05 < P < 0.10$) values in bold.

Species	Year $F_{1,48}$	Habitat $F_{1,24}$	Location $F_{2,48}$	Habitat × year $F_{1,48}$	Location × year $F_{2,48}$
Neotropical migrants					
Prothonotary Warbler	0.25	**0.002**	0.81	0.98	0.55
Acadian Flycatcher	0.22	0.30	0.20	0.74	0.86
Red-eyed Vireo	0.37	<**0.001**	**0.04**	0.42	0.16
Great-crested Flycatcher	0.19	**0.002**	0.81	0.72	0.23
Yellow-billed Cuckoo	0.38	0.59	0.55	0.87	0.70
Indigo Bunting	0.80	0.17	0.98	0.77	0.81
Eastern Wood-pewee	**0.004**	0.30	**0.02**	0.90	**0.08**
Yellow-throated Vireo	0.69	**0.002**	0.75	**0.03**	0.48
Summer Tanager	**0.08**	0.14	**0.06**	0.31	0.23
American Redstart	0.37	**0.002**	0.10	0.69	0.22
Wood Thrush	0.28	**0.002**	0.76	**0.09**	0.40
Northern Parula	0.38	<**0.001**	0.71	0.47	0.60
Short-distance migrants					
Blue-gray Gnatcatcher	<**0.001**	0.62	0.21	0.90	0.16
Common Yellowthroat	0.99	0.31	0.32	0.94	0.99
Permanent residents					
Carolina Chickadee	**0.005**	0.52	0.63	0.25	0.93
Carolina Wren	**0.001**	<**0.001**	0.37	0.15	0.72
Downy Woodpecker	0.70	**0.001**	0.56	**0.06**	0.56
Pileated Woodpecker	<**0.001**	0.70	0.44	0.32	0.31
White-breasted Nuthatch	0.18	**0.009**	0.41	0.70	0.74
Tufted Titmouse	0.78	0.49	0.11	0.83	0.51
Red-bellied Woodpecker	<**0.001**	0.43	<**0.005**	0.25	**0.008**
Northern Cardinal	0.38	**0.003**	0.14	0.52	0.82
Number significant[a]	6 + 1	11	3 + 1	1 + 2	1 + 1

[a] Total significant + marginally significant results for model term in column.

Tanager (*Piranga olivacea*), Wild Turkey (*Meleagris gallopavo*), Barred Owl (*Strix varia*), and Red-shouldered Hawk (*Buteo lineatus*).

We omitted species with fewer than 10 total detections within the 30-m radius on the 35 primary transects in both years from species-specific analyses, as well as species flying above the canopy. We excluded 1 of the remaining 24 species, Common Grackle (*Quiscalus quiscula*), because it tended to occur in large flocks, complicating statistical analyses. We excluded another species, the Brown-headed Cowbird, because most detections of this species were flyovers. The distributions of the remaining 22 species were subjected to statistical analysis (see Appendix 1 for common and scientific names).

Habitat type was much more important than patch size or proximity to edge in explaining species abundance. Half of the 22 species analyzed were significantly more common in one of the two primary habitat types than in the other (Table 1). Six species were more common in swamp forest (Prothonotary Warbler, Great Crested Flycatcher, Yellow-throated Vireo, Northern Parula, Downy Woodpecker, White-breasted Nuthatch) and five were more common in levee forest (Red-eyed Vireo, American Redstart, Wood Thrush, Carolina Wren, Northern Cardinal). We will refer to those more common in swamp forest as swamp specialists, those more common in levee forest as levee specialists, and those equally common in the two habitats as generalists.

Six species exhibited differences in abundance between years, five of which were habitat generalists (Table 1). Generally, species exhibited the same habitat associations in both years with only three species showing significant or marginally significant ($P < 0.10$) habitat $\times$ year interactions (Table 1). In all three cases, differences between years can be related to extensive flooding in 1993. Records for the first six months of 1993 indicated Roanoke River flows to be greatly above normal. Flows between 1 January 1993 and 30 June 1993 rank as the fourth highest in 83 years; flows between 1 April 1993 and 30 April 1993 were the second highest on record (Rulifson and Manooch 1993). As a result, flooding was much more extensive in 1993 than in 1992, extending even into levee forest for several weeks.

The Wood Thrush, a ground forager that was found primarily in levee forest in 1992, was rarer and less habitat specific in 1993. The Yellow-throated Vireo and Downy Woodpecker, associated with swamp forest in 1992, exhibited increased use of narrow levees in 1993 when they were extensively flooded. Two of the other four swamp specialists exhibited a similar pattern (Prothonotary Warbler, Great Crested Flycatcher), although the habitat $\times$ year interaction was not statistically significant in these cases.

In contrast to strong effects of habitat type on many species, proximity to edge had only weak effects on a few species. Four species exhibited location effects: all were habitat generalists except the Red-eyed Vireo, a levee specialist. In two of these species, the inconsistency of the location effect was manifested in a significant location $\times$ year interaction (Table 1). The Eastern Wood-pewee was more common in narrow levees and at swamp edges in 1992, but not in 1993 when the swamp-levee edge was obscured by flooding. The Red-bellied Woodpecker was more common on wide levees and in swamp interiors in 1992, but was less common in those locations in 1993. The Red-eyed Vireo was similar to the Eastern Wood-pewee in that the location effect detected was observed only in 1992, although the location $\times$ year interaction was not significant ($P = 0.16$, Table 1) in this case. Furthermore, opposite effects were observed in the two habitat types: in swamp forest, Red-eyed Vireos were more common at the locations nearest edge (swamp edges), whereas in levee forest they were more common at the locations farthest from edges (wide levees). The fourth species, the Summer Tanager, exhibited a marginally significant location effect ($P = 0.06$, Table 1) that can be described as a weak and somewhat inconsistent tendency to be detected at locations farthest from edges (wide levees, large swamp interiors).

Similarly, for only 2 of the 22 species was a relationship between forest patch size and abundance detected in regression analyses. Both cases involved specialists whose abundance within their preferred habitat was positively related to patch size. Abundance of the Prothonotary Warbler, a swamp specialist, was positively correlated with swamp forest patch size, whereas abundance of the other five swamp specialists was unrelated to swamp forest patch size (Table 2). Abundance of swamp specialists in levee forest was either too low to permit analysis (i.e., species not detected in half or more of the transects) (Northern Parula, White-breasted Nuthatch), unrelated to levee width (Prothonotary Warbler), negatively related to levee width (Downy Woodpecker), or tending toward a negative relationship with levee width (Great Crested Flycatcher, Yellow-throated Vireo) (Table 2). Among the five levee specialists, abundance of only the American Redstart was positively correlated with levee width (Table 2). In swamp forest, abundance of levee specialists was either too low to permit analysis (American Redstart, Wood Thrush), unrelated to swamp forest patch size (Carolina Wren, Northern Cardinal), or tending toward a negative relationship with swamp forest patch size (Red-eyed Vireo) (Table 2). The only relationships with patch size found among habitat generalists were negative. Abundance of Acadian Flycatchers was negatively related to size of swamp forest patches (Table 2). There was a tendency toward a similar relationship for Eastern Wood-pewees, and toward a negative relationship between levee width and abundance of Tufted Titmice (Table 2).

COMMUNITY INDICES

Insensitivity to location and patch size also was apparent when number of individuals and number of species were considered. For swamp forests in both years, there was no relationship between the number of individuals and patch size or between number of species and patch size ($r^2 < 0.12$, $P > 0.28$ in all four cases). There was no relationship between the number of individuals and levee forest width in either year (Fig. 2A), or between number of species and levee forest width in 1992 (Fig. 2B) ($r^2 < 0.20$, $P > 0.15$ in all three cases). However, there was a significant negative relationship between num-

TABLE 2. Results (r^2 values) of regression analyses of relationships of abundance of bird species with swamp forest patch size and levee forest width along the Roanoke River, North Carolina. Species more common in swamp forest are classified as swamp specialists, those more common in levee forest as levee specialists, and those equally common in the two habitats as generalists. For years with significant differences in abundance, values for 1992 (upper) and 1993 (lower) are reported separately. Species not detected indicated by (—); (+ or −) indicate direction of relationships. For all regressions, df = 1, 12. Significant relationships are indicated by * ($P < 0.05$) or ** ($P < 0.01$).

Species	Swamps	Levees
Swamp specialists		
Prothonotary Warbler	0.28 (+)*	0.06 (−)
Great-crested Flycatcher	0.12 (−)	0.18 (−)
Yellow-throated Vireo	0.16 (−)	0.15 (−)
Northern Parula	0.02 (+)	0.09 (−)
Downy Woodpecker	0.01 (+)	0.29 (−)
White-breasted Nuthatch	0.03 (+)	0.03 (−)
Levee specialists		
Red-eyed Vireo	0.14 (−)	0.07 (+)
American Redstart	—	0.16 (+)*
Wood Thrush	0.00 (−)	0.00 (+)
Carolina Wren	0.01 (−)	0.15 (−)
	0.01 (+)	0.00 (+)
Northern Cardinal	0.00 (+)	0.09 (−)
Generalists		
Acadian Flycatcher	0.40 (−)*	0.11 (+)
Yellow-billed Cuckoo	0.10 (+)	0.01 (−)
Indigo Bunting	0.12 (−)	0.01 (−)
Eastern Wood-pewee	0.19 (−)	0.07 (−)
	0.17 (−)	0.03 (−)
Summer Tanager	0.01 (−)	0.01 (+)
Blue-gray Gnatcatcher	0.05 (−)	0.09 (+)
	0.01 (−)	0.06 (+)
Common Yellowthroat	0.19 (+)	0.03 (−)
Carolina Chickadee	0.15 (−)	0.00 (+)
	0.02 (−)	0.00 (+)
Pileated Woodpecker	0.04 (−)	0.02 (−)
	0.06 (+)	0.00 (+)
Tufted Titmouse	0.07 (+)	0.27 (+)*
Red-bellied Woodpecker	0.02 (−)	0.04 (+)
	0.16 (+)	0.05 (−)

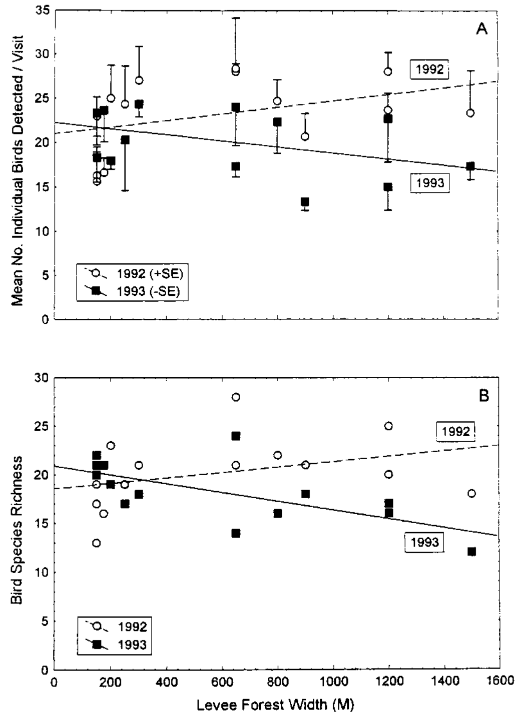


FIGURE 2. Number of individuals (A) and species (B) as a function of levee forest width.

ber of species and levee forest width in 1993 ($r^2 = 0.43$, $F_{1,12} = 9.00$, $P = 0.01$) (Fig. 2B), when narrow levees were flooded.

DISCUSSION

The lower Roanoke River floodplain is clearly an important breeding area for many birds, including Neotropical migratory species. The two most common birds breeding on the floodplain are Neotropical migrants (Prothonotary Warbler and Acadian Flycatcher). The abundances recorded for these species, and several others such as Pileated Woodpecker, are remarkable. At the community level, avian abundance and species richness are similar to, if not higher than, those reported for other bottomland hardwood forests (Mitchell and Lancia 1990, Smith et al. 1995). The Roanoke bottomland forests contain a large population of a migratory species that is otherwise uncommon in the North Carolina Coastal Plain (American Redstart), and small but significant populations of two migrants of regional concern (Swainson's Warbler, Cerulean Warbler, the latter of which also is otherwise absent from the North Carolina Coastal Plain).

The value of the primary habitat types found along the Roanoke varies among species. Some birds prefer swamps (Northern Parula and White-breasted Nuthatch) and some favor levees (Red-eyed Vireo and Northern Cardinal), whereas others use swamps and levees equally (Acadian Flycatcher and Pileated Woodpecker) (Table 1). Bird-habitat associations were strong and consistent between years. Where differences occurred between 1992 and 1993, they were most likely related to the extensive flooding that occurred in 1993, which probably promoted intrusion of swamp specialists into at least narrow levees and reduced habitat available to ground-dwelling levee specialists. A notable habitat association was that between giant cane and several uncommon species, including Swainson's Warbler. One management activity that would increase the conservation value of the Roanoke forests would be to increase the abundance of cane.

PATCH SIZE AND EDGE EFFECTS

Although we readily detected habitat preferences, we detected few effects of patch size or proximity to edge among the 35 primary transects. Proximity to edge, in fact, more frequently had positive effects on abundance of individual species than negative effects. The only consistent pattern we detected is that species characteristic of one habitat type tended to be more abundant within the second habitat type near edges. This presumably reflects proximity to the preferred habitat. In addition, one species, the Eastern Wood-pewee, appeared to be more abundant along edges between levee and swamp than within either habitat.

Of the four species (Acadian Flycatcher, Northern Parula, American Redstart, and Pileated Woodpecker) included in our analyses classified as ''forest interior species'' by Whitcomb et al. (1981) and Freemark and Merriam (1986), only the American Redstart was more common in larger patches along the Roanoke. Within swamp forest, the Acadian Flycatcher actually was less abundant in larger patches. Our results differ from those of other studies that indicate bird density and species richness to be proportional to patch size (Freemark and Merriam 1986, Blake and Karr 1987, Loyn 1987), and to riparian forest width (Stauffer and Best 1980, Keller et al. 1993). Among bottomland hardwood forest corridors of different widths studied in Georgia, wider corridors had richer avian communities (Hodges and Krementz 1996). Species-specific analyses indicated positive relationships with corridor width for several species, including three (Northern Parula, Red-eyed Vireo, Blue-gray Gnatcatcher) for which we found no such relationships. We did, however, find a positive relationship for Prothonotary Warblers, as did Hodges and Krementz (1996), and we found evidence of higher abundance in smaller swamp forest patches for the one species, the Acadian Flycatcher, for which Hodges and Krementz (1996) found a negative relationship between abundance and corridor width.

An obvious difference between our study and those cited above is that the forest patches we studied were bordered by other types of forest or river rather than by agricultural or suburban lands, or in the case of Hodges and Krementz (1996), pine plantations. The narrow levees we sampled were as narrow as the forest corridors in which Hodges and Krementz (1996) found abundances to be reduced, but the entire forest matrix in which they were embedded was much wider. These results suggest that effects of patchiness, including fragmentation, are dependent on the nature of edges (Schieck et al. 1995, Saurez et al. 1997) and intervening habitats. For some species, such as American Redstarts and Prothonotary Warblers, effects of patch size may hold across a variety of landscapes, reflecting perhaps basic features of population dynamics. For other species, effects of patch size and edge may be landscape-specific, reflecting a particular interaction between that landscape and population dynamics. This thesis is consistent with studies that report numerous patch size effects in naturally patchy systems where edge and habitat contrasts are high (Helle 1985, Dobkin and Wilcox 1986), and with studies that have shown fragmentation by silviculture to have fewer effects than fragmentation by agriculture (Haila et al. 1989, Lemkuhl et al. 1991, Schieck et al. 1995). Silviculture creates forest edges that are transient in nature and less abrupt (DeGraaf 1992, McGarigal and McComb 1995), perhaps thereby reducing edge-related phenomena such as nest predation and brood parasitism (Rudnicky and Hunter 1993, Hanski et al. 1996, King et al. 1996). In our study area, predation on artificial nests is higher along edges between forest and agricultural areas than along edges between forest types or between forest and the river (Saracco and Collazo 1999).

Effects of fragmentation are not always manifested in changes in abundance. For example, in the Midwest, regional movements maintain abundance of many species in small forest patch and edge sinks, despite extremely high levels of nest predation and parasitism (Robinson et al. 1995, Faaborg et al. 1998). This is likely only in systems in which fragmentation (or patchiness) does not disrupt dispersal. Perhaps small swamp forest patches along the Roanoke are sinks as well, but this is not reflected in differences in abundance because the landscape is conducive to the movement of birds from productive large patches to unproductive small ones. We think this possibility unlikely, but cannot rule it out until sufficient data on productivity and mortality are available. Studies of reproduction and mortality are necessary to determine whether population dynamics, like abundance, are little affected by patch size and edges.

Factors other than a species–area relationship may account for much of the variation in bird-habitat associations such as those studied here. A lack of sensitivity to area may in fact be related to factors not measured or incorporated in analyses (e.g., degree of isolation, floristics, forest physiognomy, food resources, or nest sites). Such factors have been found to be as important, or more important, than area per se in explaining species abundance patterns in patches of varying sizes and isolation (Rafe et al. 1985, Boecklen 1986).

This initial study indicates the value of the Roanoke bottomland forests as a reserve for birds to be extremely high potentially. Many species are abundant, including several Neotropical migratory species that are rare in the region. It remains to be determined whether these species are able to maintain their populations in this area. If, but only if, productivity and survival are high, the Roanoke forests may house not only locally sustainable populations, but also regionally important source populations.

ACKNOWLEDGMENTS

This study was funded by The Nature Conservancy, the National Fish and Wildlife Foundation, and the U.S. Fish and Wildlife Service. We especially thank J. M. Lynch of The Nature Conservancy for his many contributions to all aspects of the project, including the selection of sites for transect location. J. Holloman, Manager of the Roanoke River National Wildlife Refuge, provided generous support and technical assistance throughout the study. S. R. Sallabanks, M. Wilson, S. B. Anderson, and M. Anjaneyulu assisted with data collection. W. P. Smith, J. Hagar, W. D. Koenig, and three anonymous reviewers provided constructive, critical reviews of earlier versions of this paper. M. Gumpertz offered statistical advice. Finally, we thank the following land-owners along the Roanoke for allowing us access to their property: The Nature Conservancy, the U.S. Fish and Wildlife Service, the North Carolina Wildlife Resources Commission, Georgia Pacific, Timberlands Unlimited, Inc., Union Camp, North Carolina Department of Corrections, A. McLennon, J. G. Burgwyn, S. Graves, M. Ranson, B. Johnston, and B. Johnson.

LITERATURE CITED

ABERNATHY, Y., AND R. TURNER. 1987. U.S. forested wetlands: status and changes 1940–1980. BioScience 37:721–727.

ANDRÉN, H., AND P. ANGELSTAM. 1988. Elevated predation rates as an edge effect in habitat islands: experimental evidence. Ecology 69:544–547.

ASKINS, R. A., J. F. LYNCH, AND R. GREENBERG. 1990. Population declines in migratory birds in eastern North America. Current Ornithol. 7:1–57.

BLAKE, J. G., AND J. R. KARR. 1987. Breeding birds of isolated woodlots: area and habitat relationships. Ecology 68:1724–1734.

BOECKLEN, W. J. 1986. Effects of habitat heterogeneity on the species–area relationships of forest birds. J. Biogeogr. 13:59–68.

BRITTINGHAM, M. C., AND S. A. TEMPLE. 1983. Have cowbirds caused forest songbirds to decline? BioScience 33:31–35.

DEGRAAF, R. M. 1992. Effects of even-aged management on forest birds at northern hardwood stand interfaces. For. Ecol. Manage. 46:95–110.

DOBKIN, D. S., AND B. A. WILCOX. 1986. Analysis of natural forest fragments: riparian birds in the Toiyabe mountains, Nevada, p. 293–299. *In* J. Verner, M. L. Morrison, and C. J. Ralph [EDS.], Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Univ. Wisconsin Press, Madison, WI.

DONOVAN, T. M., F. R. THOMPSON III, J. FAABORG, AND J. R. PROBST. 1995. Reproductive success of migratory birds in habitat sources and sinks. Conserv. Biol. 9:1380–1395.

FAABORG, J., M. BRITTINGHAM, T. DONOVAN, AND J. BLAKE. 1995. Habitat fragmentation in the Temperate Zone, p. 357–380. *In* T. E. Martin and D. M. Finch [EDS.], Ecology and management of Neotropical migratory birds. Oxford Univ. Press, Oxford.

FAABORG, J., F. R. THOMPSON III, S. K. ROBINSON, T. M. DONOVAN, D. R. WHITEHEAD, AND J. BRAWN. 1998. Understanding fragmented Midwestern landscapes: the future, p. 193–207. *In* J. M. Marzluff and R. Sallabanks [EDS.], Avian conservation: research and management. Island Press, Washington, DC.

FREEMARK, K. E., AND H. G. MERRIAM. 1986. Importance of area and habitat heterogeneity to bird assemblages in temperate forest fragments. Biol. Conserv. 36:115–141.

GATES, J. E., AND L. W. GYSEL. 1978. Avian nest dispersion and fledgling success in field-forest ecotones. Ecology 59:871–883.

HAILA, Y., I. K. HANSKI, AND S. RAIVIO. 1989. Methodology for studying the minimum habitat requirements of forest birds. Annales Zoologici Fennici 26:173–180.

HANSKI, I. K., T. J. FENSKE, AND G. J. NIEMI. 1996. Lack of edge effect in nesting success of breeding birds in managed forest landscapes. Auk 113:578–585.

HARRIS, L. D. 1988. Edge effects and conservation of biotic diversity. Conserv. Biol. 2:330–332.

HARTLEY, M. J., AND M. L. HUNTER JR. 1998. A metaanalysis of forest cover, edge effects and artificial nest predation rates. Conserv. Biol. 12:465–469.

HELLE, P. 1985. Effects of forest fragmentation on bird densities in northern boreal forests. Ornis Fennica 62:35–41.

HODGES, M. F., JR., AND D. G. KREMENTZ. 1996. Neotropical migratory breeding bird communities in riparian forests of different widths along the Altamaha River, Georgia. Wilson Bull. 108:496–506.

HOOVER, J. P., M. C. BRITTINGHAM, AND L. J. GOODRICH. 1995. Effects of forest patch size on nesting success of Wood Thrushes. Auk 112:146–155.

HUTTO, R. L., S. M. PLETSCHET, AND P. HENDRICKS. 1986. A fixed-radius point count method for nonbreeding and breeding season use. Auk 103:593–602.

JMP. 1994. Software for statistical visualization for Windows. Version 3.2.2. JMP, Cary, NC.

KELLER, C. M. E., C. S. ROBBINS, AND J. S. HATFIELD. 1993. Avian communities in riparian forests of different widths in Maryland and Delaware. Wetlands 13:137–144.

KING, D. I., C. R. GRIFFIN, AND R. M. DEGRAAF. 1996. Effects of clearcutting on habitat use and reproductive success of the Ovenbird in forested landscapes. Conserv. Biol. 10:1380–1386.

LEE, D. S., AND J. F. PARNELL. [EDS.]. 1990. Endangered, threatened, and rare fauna of North Carolina. Part III. A re-evaluation of the birds. North Carolina Biol. Survey and North Carolina State Mus. Nat. Sci., Raleigh, NC.

LEMKUHL, J. F., L. E. RUGGIERO, AND P. A. HALL. 1991. Landscape patterns of forest fragmentation and wildlife richness and abundance in the southern Washington Cascade range, p. 425–442. *In* L. F. Ruggiero, K. B. Aubry, A. B. Carey, and M. H. Hutt [TECH. COORDS.], Wildlife and vegetation in unmanaged Douglas-fir forests. USDA Forest Service, Pacific Northwest Res. Sta., Gen. Tech. Rep. PNW-GTR-285, Portland, OR.

LEVENE, H. 1960. Robust tests for equality of variances, p. 278–292. *In* I. Olkin, S. G. Ghurye, W. Hoeffding, W. G. Mado, and H. B. Mann [EDS.], Contributions to probability and statistics. Stanford Univ. Press, Stanford, CA.

LOYN, R. H. 1987. Effects of patch area and habitat on bird abundances, species number and tree health in fragmented Victorian forests, p. 65–77. *In* D. A. Saunders, G. W. Arnold, A. A. Burbridge, and A. J. M. Hopkins [EDS.], Nature conservation: the role of remnants of native vegetation. Surrey Beatty and Sons, Chipping Norton, UK.

MCGARIGAL, K., AND W. C. MCCOMB. 1995. Relationships between landscape structure and breeding birds in the Oregon Coast Range. Ecol. Monogr. 65:235–260.

MITCHELL, L. J., AND R. A. LANCIA. 1990. Breeding bird community changes in bald-cypress-tupelo wetland following timber harvesting. Proc. Annu. Conf. Southeast. Assoc. Fish Wildl. Agencies 44: 189–201.

MITCHELL, L. J., R. A. LANCIA, R. LEA, AND S. A. GAUTHREAUX JR. 1991. Effects of clearcutting and natural regeneration on breeding bird communities of bald-cypress-tupelo wetlands, p. 155–161. *In* J. Kusler and S. Daly [EDS.], Proceedings of symposium on wetlands and river corridor management. Assoc. Wetland Managers, Berne, NY.

PASHLEY, D. N., AND W. C. BARROW. 1992. Effects of land use practices on Neotropical migratory birds in bottomland hardwood forests, p. 315–320. *In* D. M. Finch and P. W. Stangel [EDS.], Status and management of Neotropical migratory birds. USDA Forest Service, Rocky Mountain Forest and Range Experimental Station, Gen. Tech. Rep. Rm-229, Fort Collins, CO.

PULLIAM, H. R. 1988. Sources, sinks, and population regulation. Am. Nat. 132:652–661.

RAFE, R. W., M. B. USHER, AND R. G. JEFFERSON. 1985. Birds on reserves: the influence of area and habitat on species richness. J. Appl. Ecol. 22:327–335.

ROBINSON, S. K., F. R. THOMPSON III, T. M. DONOVAN, D. R. WHITEHEAD, AND J. FAABORG. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987–1990.

RUDNICKY, T. C., AND M. L. HUNTER. 1993. Avian nest predation in clearcuts, forests, and edges in a forest-dominated landscape. J. Wildl. Manage. 57: 358–364.

RULIFSON, R. A., AND C. S. MANOOCH III [EDS.]. 1993. Roanoke River water flow committee report for 1991–1993. Albemarle-Pamlico estuarine study, Project No. Apes 93–18, North Carolina Department of Environment, Health and Natural Resources, Raleigh, NC.

SARACCO, J. F., AND J. A. COLLAZO. 1999. Predation on artificial nests along three edge types in a North Carolina bottomland hardwood forest. Wilson Bull. 111:541–549.

SAUREZ, A. V., K. S. PFENNIG, AND S. K. ROBINSON. 1997. Edges are not all equal: nesting success of a disturbance-dependent songbird. Conserv. Biol. 11:928–935.

SCHAFALE, M. P., AND A. S. WEAKLEY. 1990. Classification of the natural communities of North Carolina: third approximation. North Carolina Natural Heritage Program, Raleigh, NC.

SCHIECK, J., K. LERTZMAN, B. NYBERG, AND R. PAGE. 1995. Effects of patch size on birds in old-growth montane forests. Conserv. Biol. 9:1072–1084.

SCHWARTZ, M. W. [ED.]. 1997. Conservation in highly fragmented landscapes. Chapman and Hall, New York.

SMITH, W. P., D. J. TWEDT, R. J. COOPER, D. A. WIEDENFELD, P. B. HAMEL, AND R. P. FORD. 1995. Sample size and allocation of effort in point count sampling of birds in bottomland hardwood forests, p. 7–18. *In* C. J. Ralph, J. R. Sauer, and S. Droege [EDS.], Monitoring bird populations by point counts. USDA Forest Service, Pacific Southwest Research Station, Gen. Tech. Rep. PSW-GTR-149, Albany, CA.

STAUFFER, D. F., AND L. B. BEST. 1980. Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. J. Wildl. Manage. 44: 1–15.

TURNER, R. E., S. FORSYTHE, AND N. CRAIG. 1981. Bottomland hardwood forest land resources of the southeastern U.S., p. 13–18. *In* J. R. Clark and J. Benforado [EDS.], Wetlands of bottomland hardwood forest. Elsevier, New York.

WALTERS, J. R. 1998. The ecological basis of avian sensitivity to habitat fragmentation, p. 181–192. *In* J. M. Marzluff and R. Sallabanks [EDS.], Avian conservation: research and management. Island Press, Washington, DC.

WHARTON, C. H., V. W. LAMBOUR, J. NEWSON, P. V. WINGER, L. L. GADDY, AND R. MANCKE. 1981. The fauna of bottomland hardwoods in the southeastern United States, p. 87–160. *In* J. R. Clark and J. Benforado [EDS.], Wetlands of bottomland hardwood forest. Elsevier, New York.

WHITCOMB, R. F., C. S. ROBBINS, J. F. LYNCH, B. L. WHITCOMB, M. K. KLIMKIEWICZ, AND D. BYSTRAK. 1981. Effects of forest fragmentation on avifauna of the eastern deciduous forest, p. 125–206. *In* R. L. Burgess and D. M. Sharpe [EDS.], Forest island dynamics in man-dominated landscapes. Springer-Verlag, New York.

APPENDIX 1. Species included in statistical analyses of individual species' distributions.

Neotropical migrants	
Prothonotary Warbler	*Protonotaria citrea*
Acadian Flycatcher	*Empidonax virescens*
Red-eyed Vireo	*Vireo olivaceus*
Great-crested Flycatcher	*Myiarchus crinitus*
Yellow-billed Cuckoo	*Coccyzus americanus*
Indigo Bunting	*Passerina cyanea*
Eastern Wood-pewee	*Contopus virens*
Yellow-throated Vireo	*Vireo flavifrons*
Summer Tanager	*Piranga rubra*
American Redstart	*Setophaga ruticilla*
Wood Thrush	*Hylocichla mustelina*
Northern Parula	*Parula americana*
Short-distance migrants	
Blue-gray Gnatcatcher	*Polioptila caerula*
Common Yellowthroat	*Geothlypis trichas*
Permanent residents	
Carolina Chickadee	*Parus carolinensis*
Carolina Wren	*Thryothorus ludovivianus*
Downy Woodpecker	*Picoides pubescens*
Pileated Woodpecker	*Dryocopus pileatus*
White-breasted Nuthatch	*Sitta carolinensis*
Eastern Tufted Titmouse	*Parus bicolor*
Red-bellied Woodpecker	*Melanerpes carolinus*
Northern Cardinal	*Cardinalis cardinalis*

Ecological Applications, 10(5), 2000, pp. 1356–1366

PREDICTING PRESENCE AND ABUNDANCE OF A SMALL MAMMAL SPECIES: THE EFFECT OF SCALE AND RESOLUTION

JOHN L. ORROCK,[1,4] JOHN F. PAGELS,[1] WILLIAM J. MCSHEA,[2] AND ELIZABETH K. HARPER[3]

[1]*Department of Biology, Virginia Commonwealth University, Richmond, Virginia 23284-2012 USA*
[2]*Conservation and Research Center, Smithsonian Institution, Front Royal, Virginia 22630 USA*
[3]*Department of Fisheries and Wildlife, University of Minnesota, St. Paul, Minnesota 55108 USA*

Abstract. Management of small mammal communities in forest ecosystems requires a working knowledge of the scales at which species presence and abundance can best be predicted. Habitat-based models were developed to characterize the distribution of a boreal relict, the southern red-backed vole, *Clethrionomys gapperi,* in the southern Appalachian Mountains, USA, at three hierarchical scales of analysis. Vole presence and abundance were most evident at the high-resolution (macrohabitat) scale, followed by the intermediate-resolution scale. The low-resolution model was the least effective for predicting presence or abundance and reflects the need for more resolute landscape classification systems if small mammal populations are to be accounted for in an ecologically relevant manner. Tree and shrub communities indicative of suitable vole habitat included *Fraxinus pennsylvanica* and *Tsuga canadensis* in the canopy and *Carpinus caroliniana* in the understory. Vole abundance increased with incidence of tree species such as *Betula alleghaniensis, Pinus rigida,* and *Prunus serotina* in the canopy, and *Acer spicatum* and woody vines in the understory. Voles were associated with northwest-facing high-elevation sites with abundant rocky substrate, likely a reflection of physiological water and thermal requirements, biogeographic influences, and the importance of substrate complexity for decreasing inter- and intraspecific interactions and avoidance of predators.

Identification of the most effective resolution of landscape characterization improves habitat-based models of *C. gapperi* population dynamics in managed landscapes. Low-resolution habitat classifications may suffice for detecting suitable vole habitats within forest types, but prediction of vole abundance is most accurate at the greatest resolution, i.e., the macrohabitat scale. The utility of forest communities and habitats at various scales to predict vole presence and abundance suggests that *C. gapperi* may be a useful indicator species for identification and assessment of habitat important for rare small mammal species in the southern Appalachians.

Key words: Appalachian Mountains, USA; Clethrionomys gapperi; *habitat selection; indicator species analysis; landscape classification; logistic regression; population ecology.*

INTRODUCTION

Habitat selection affects the distribution of animals across landscapes (Pulliam and Danielson 1991, Dunning et al. 1992). Knowledge of the way in which organisms select habitat is useful for understanding the components that govern ecological systems and for predicting changes in community structure that might follow natural or anthropogenic alterations of ecosystems (Dunning et al. 1995). Because processes that govern habitat selection vary across landscapes and scales of analysis (Thomas and Taylor 1990), ignoring scale risks drawing incorrect conclusions regarding habitat use and importance (Wiens et al. 1987). The measurement of landscape characteristics (Levin 1992) and the perception of density-dependence in a landscape are scale-dependent (Bowers and Matter 1997). Simply, "reality is size dependent" (S. Vogel as quoted in LaBarbera 1989), and examining the habitat-specific responses of organisms should utilize a scalar approach to yield the most ecologically relevant conclusions (Morris 1987*a*, Stapp 1997).

Spatially explicit models, which incorporate landscape structure and habitat utilization to predict population responses to landscape change (Dunning et al. 1995, Turner et al. 1995), could benefit from increased predictive ability conferred by using appropriate scales of habitat characterization (Pulliam et al. 1994, Dunning et al. 1995). Understanding how populations are affected by neighboring populations (Pulliam et al. 1994) and how barriers, corridors, and neighboring patches are detected in the landscape depends upon accurate description of landscape boundaries as perceived by study organisms (Dunning et al. 1995). Once the scales of importance have been determined, managers can find a balance between economy of landscape analysis and predictive power with the population of interest.

Manuscript received 19 March 1999; revised 18 August 1999; accepted 9 September 1999.

[4] Present address: Department of Animal Ecology, 124 Science II, Iowa State University, Ames, Iowa 50011 USA. E-mail: jorrock@iastate.edu

Populations of interest are often composed of rare organisms of special management concern (Wiser et al. 1998). The creation of predictive models with more abundant indicator species provides a tool that managers can use to identify areas where rare species are likely to be found. In this case, one study may address several important issues, i.e., examining the scales at which presence and abundance are best predicted for an indicator species allows us to unravel the ecology of the indicator species and provides a means to assess habitat quality for more rare species. Because of moderate dispersal ability (Couch 1998), relative ease of capture, and known association with rare species (Pagels and Tate 1976, Payne et al. 1989, Pagels 1990), the southern red-backed vole, *Clethrionomys gapperi,* provides a model study organism for addressing these issues.

Clethrionomys gapperi is an arvicoline rodent whose distribution ranges from the northern reaches of Canada to the southern portion of the Appalachian Mountains in the eastern United States (Merritt 1981). Once more widespread, post-Pleistocene warming caused *C. gapperi* to withdraw to higher elevation areas in the southern Appalachians (Guilday 1971, Handley 1971). *Clethrionomys* inhabits boreal, mesic forests, as well as recent clearcuts (Steblein 1984, Kirkland 1990). Previous research has noted the characteristics of vole habitat (Fisher 1968, Miller 1970, Merritt 1981, Steblein 1984). However, the response of voles to managed habitats varies (summary in Kirkland 1990), suggesting that habitat selection of *C. gapperi* is not yet completely understood. Morris (1989) and Knight and Morris (1996) have examined vole distribution at multiple scales in Canada, but utilized only a few different habitat types to discern the scales of importance. Our examination extends their work, seeking to identify how *C. gapperi* is distributed within a highly managed landscape composed of many habitat types over a wide expanse.

Our study investigated habitat attributes important for *Clethrionomys* presence and abundance at three scales across a managed landscape with forests of varying species and age composition. Because scale is composed of several characteristics, we examined habitats at varying degrees of resolution, i.e., while the geographic magnitude (extent) remained the same (E. J. Cushing, *personal communication*), information was added regarding the habitats at each subsequent level of analysis, resulting in a gradient from coarse- to fine-grained descriptions of habitat. The habitat analysis was performed in a hierarchical manner (Johnson 1980, Kolasa 1990, Kotliar and Wiens 1990): (1) low-resolution analysis treated the landscape as being composed of seven habitat types; (2) intermediate-resolution analysis treated the landscape as being composed of 15 habitat types; and (3) high-resolution (macrohabitat scale, sensu Morris 1987*a*) analysis treated landscape as being composed of 349 sampling sites. We suspected that presence and abundance of voles might be most evident at different scales of analysis. As such, we examined presence and abundance separately to determine whether red-backed voles perceive these components of habitat differently. If hierarchical selection was applicable, we expected presence to be most evident at lower resolution, while vole abundance should respond to local habitat factors most evident at higher resolution, i.e., the macrohabitat scale.

Red-backed voles are habitat associates of rare small mammals in the region including *Sorex palustris* (Pagels and Tate 1976), *Microtus chrotorrhinus* (Pagels 1990), and *Glaucomys sabrinus* (Payne et al. 1989), and other investigators have suggested that *C. gapperi* might serve as a useful indicator species (Nordyke and Buskirk 1988). As such, models useful for identifying habitat with abundant *C. gapperi* may be useful for the management of rare mammal as well as amphibian species (Pagels et al. 1994, Mitchell et al. 1997). To maximize utility, models were generated using information readily taken from forest inventory data or easily measured by field technicians, such as tree and shrub species, substrate characteristics, and field capacity. Promising management protocols based upon integration of field data, satellite imagery, and GIS technology are still limited in their ability to discern fine-scale differences in habitat. Hence, our large-scale models represent those that could be detected with such technology (He et al. 1998). Through these models, we hoped to determine the utility of large-scale management techniques as they pertain to examining small mammal populations and provide suggestions for their improvement.

The null hypothesis states that *C. gapperi* select habitats equally at all scales, and an examination of habitats at all resolutions will be equally effective in predicting *C. gapperi* presence and abundance. Our objectives were to determine: (1) the scale at which the pattern of red-backed vole distribution was most evident; (2) the ecological factors responsible for red-backed vole distribution patterns; and (3) if both were evident at the same scale of analysis.

Materials and Methods

Study area

The survey area consisted of a 160-km^2 portion of the George Washington and Jefferson National Forests in the southern Appalachian Mountains between 38°28′–38°02′ N and 79°40′–79°50′ W. The sampling area was located on, or adjacent to, a portion of the Allegheny Mountain that extends from Hightown to Mountain Grove, Virginia. Sampling sites (hereafter referred to as sites) within the area were chosen randomly within 25 age/habitat classes as defined using United States Forest Service Continuous Inventory of Stand Condition (CISC) data. The number of sites placed in a given habitat type was proportional to the area of that habitat type in the study region, i.e., most habitats were assessed according to their relative availability (Thomas and Taylor 1990). We manually increased the number of rare habitat types sampled to maintain a minimum number of replicates for subsequent analysis; 349 sites were established. Boundaries of all sites were at least 250 m apart and at least 20 m from the edge of the given habitat type. Site location was determined with a Trimble GPS Pathfinder Pro XL and coordinates were corrected using base station data from the Harrisonburg, Virginia office of the U.S. Forest Service.

Survey and collection methodology

Each site was a circular area, 22 m in diameter, with trap stations established within the site at each cardinal direction near the site perimeter. At each station, two $8 \times 9 \times 23$ cm Sherman live traps (H. B. Sherman Traps, Tallahassee, Florida, USA) were placed at likely capture spots within a 2-m radius extending from the site perimeter towards the center. A single $21 \times 21 \times 62$ cm Tomahawk live trap (Tomahawk Live Trap Company, Tomahawk, Wisconsin, USA) was placed within each site. Sherman live traps were baited with whole oats covered with either peanut butter or peanut oil. Tomahawk traps were baited with sunflower seeds. Synthetic bedding material was placed in all traps, and traps were covered with a roofing shingle or leaf litter to provide shelter. A pitfall array was installed within each sample site consisting of a center pitfall surrounded by three other pitfalls spaced 1 m from the center (Type 1B of Handley and Kalko 1993). Each 0.5-L pitfall was connected to the center pitfall by a drift fence made of a 0.3 m high aluminum screening. Pitfalls were filled with ~5 cm of water during trapping and were closed after use.

A 7-d trap session was conducted at each site; a typical session included 30 sites of various habitat types. Pitfall traps were open for seven consecutive days; live traps were pre-baited for two days and then opened for five consecutive days. All traps were checked daily for captures and live traps rebaited as necessary. Specimens were marked with a No.1 monel eartag (National Band and Tag Company, Lexington, Kentucky, USA), and species, sex, age, and mass recorded before release. Dead specimens were injected with 10% formalin solution and deposited in the Virginia Commonwealth University Mammal Collection.

Climatological data were obtained from the weather station at the Bath County Hydroelectric Pump/Storage Facility located near the center of the study area. Trapping sessions were partitioned into seasons by examining plots of data for mean monthly minimum, maximum, and daily temperatures in 1996 and 1997. Sites trapped between 12 May and 10 June were designated spring, those trapped between 26 June and 14 August were designated summer, and autumn sites were trapped between 31 August and 12 September. Sites were partitioned into spring (113 sites), summer (158 sites) and autumn (78 sites). Daily temperatures in the spring (14.6° ± 0.3°C, mean ± 1 SE), summer (21.4° ± 0.6°C), and autumn (19.6° ± 0.2°C) were significantly different (paired *t* tests, $P < 0.01$).

Site analysis

Slope was determined using a Suunto PM-51360 clinometer, and aspect was determined with a compass by estimating the direction water would flow from the center of a site. All woody plants >1 m in height within the site were counted and identified to species. The diameter at breast height (dbh; breast height ~1 m) was recorded for all trees, defined as woody plants with a dbh >0.04 m and height >1 m. Canopy openness, ground cover, and substrate composition were determined using the line-transect method of Canfield (1941). Two transects were established that divided the study area into four equal quarters, bisecting in the center. Along each transect, 40 observations were made using an ocular tube. We tallied observations in the following categories: herbaceous material, leaf litter, bare soil, rock, woody debris, moss, lichen, and whether the canopy was open or closed. One sample point along a transect could yield several tallies, e.g., if a moss-covered rock was shaded by herbaceous vegetation. Tallies of rock were sized according to the following scheme: size 1 <0.2 m, size 2 = 0.2–0.4 m, size 3 = 0.41–0.8 m, and size 4 > 0.8 m. We considered woody debris to be any portion of a woody stem or trunk regardless of the size; the diameter of large woody debris (diameter estimated to be >0.1 m) along the transect was estimated and recorded. In addition to transect data, we counted all downed logs with a diameter >10 cm within each site (Table 1).

Soil was sampled by taking random core samples to a depth of 0.1 m using a 2 cm diameter galvanized pipe section driven into the soil; rocky conditions necessitated use of a pick mattock at some sites. We collected one sample of the top mineral soil horizon from each quadrant of the site, excluding the top layer of organic material and humus. All soil samples were stored on ice and subsequently frozen until laboratory analysis. Prior to analysis, soil samples (excluding the humus layer) were pooled for each site. Moisture holding capacity (field capacity) was determined as in Salter and Williams (1967).

Data treatment

Aspect data were transformed as outlined in Beers et al. (1966) to derive a linear score from the original circular aspect data. In this manner, a score between 0 (southeast aspect) and 2 (northwest aspect) represented aspect at each site. Proportional basal area and proportional abundance of each tree species were summed to generate the importance values for tree species at each site. Importance values were standardized, and the resulting proportions were arcsine square-root trans-

TABLE 1. Variables used to quantify habitat characteristics at study sites in the southern Appalachian Mountains, USA, and the respective abbreviations used in the text.

Scale of analysis	Variable name	Description
Low resolution	n/a	Design variable representing one of seven habitat types
Intermediate resolution	n/a	Design variable representing one of 15 habitat types
High resolution		
Topographic position	ASPECT	Aspect transformed to a value between 0 and 2
	ELEV	Elevation as determined by GPS data
	SLOPE	Inclination of site taken along aspect
Woody components	n/a	Importance value of a tree species
	CANPY	Degree of canopy closure
	SHBTOT	Count of woody shrubs dbh <4 cm and height <1 m
	TOTDBH	Sum of basal area of trees within site
	TRE410	Count of trees with dbh 4–10 cm
	TRE1125	Count of trees with dbh 11–25 cm
	TRE2660	Count of trees with dbh 26–60 cm
	TRE61	Count of trees with dbh >60 cm
	VINES	Sum of importance values for woody vines
Substrate	FC	Field capacity (moisture-holding ability of soil at a site)
	HERB	Percentage of incidence of herbaceous vegetation
	HMHAB	Shannon index measure of substrate diversity
	LEAF	Percentage of incidence of leaf
	LICHEN	Percentage of incidence of lichen
	LOGS	Count of all downed logs diameter >10 cm
	MOSS	Percentage of incidence of moss
	ROCK1	Percentage of incidence of rock <20 cm wide
	ROCK2	Percentage of incidence of rock 20–40 cm wide
	ROCK3	Percentage of incidence of rock 41–80 cm wide
	ROCK4	Percentage of incidence of rock >80 cm wide
	SOIL	Percentage of incidence of bare soil
	WDYDEB	Percentage of incidence of woody debris
	WOODSUM	Sum of estimated diameter of woody debris >10 cm

Notes: Variables were transformed as described in *Materials and methods: Data treatment.*

formed to more approximate normality (Zar 1996). Additional macrohabitat variables representing density of shrubs and trees of various size classes (Table 1) were also examined for relationships with vole presence or abundance. Macrohabitat variables representing substrate components (Table 1) were also standardized and arcsine square-root transformed. Prior to use in regression analysis, all variables were examined for linear responses with the dependent variable. If a nonlinear relationship was detected, variables were transformed or additional variables were added to represent squared or cubed components of the polynomial (Hosmer and Lemeshow 1989, Jongman et al. 1995). Outliers, heteroscedasticity, independence, and normality were assessed using methods outlined in Fox (1991).

Description of scales

Cluster analysis using relative Euclidean distance (Jongman et al. 1995) and the flexible beta linkage method, with $\beta = -0.25$ (Lance and Williams 1967) was used to create low- and intermediate-resolution habitat types based upon tree importance values at each site. The number of final groups was determined by examining group placement in ordination space with detrended correspondence analysis (DCA, McCune and Mefford 1995) and was statistically evaluated using Indicator Species Analysis (Dufrêne and Legendre 1997).

Low-resolution habitat types consisted of seven habitat types; intermediate-resolution habitat types consisted of 15 habitat types (Table 2; Fig. 1). Because the analysis was hierarchical, three of the habitats at the low-resolution scale were split, while the remaining four groups were more homogeneous and remained intact in the intermediate-resolution classification (Table 2). Habitat types loosely follow Eyre (1980), which should be consulted for further description of canopy and understory species associated with each habitat type. These groups were categorized by dominant tree species in each stand type and coded as design variables (Hosmer and Lemeshow 1989) for entry into regression analyses. With the exception of the mixed mesophytic group, these groups will be referred to within the text by the common name of the dominant tree species within the group.

Macrohabitat (high-resolution) models were generated using importance values and variables relating biotic and abiotic structure (Table 1). Variables were entered without the use of data reduction via factoring as found in other studies (Morris 1984, 1987*a*, Adler and Wilson 1987, Knight and Morris 1996). Although factoring techniques combine collinear variables and attempt to discern underlying environmental gradients, all factoring methods have inherent shortcomings (Jongman et al. 1995, McCune and Mefford 1995). Because no final model suffered from excessive mul-

TABLE 2. Classification of habitats based upon flexible beta clustering of tree importance values using relative Euclidean distance.

Low resolution			Intermediate resolution		
Habitat type (code)	No. sites	Dominant tree species	Habitat type (code)	No. sites	Dominant tree species
Mixed mesophytic (MM)	59	*Betula alleghaniensis* *Fraxinus americana* *Fagus grandifolia*	Yellow birch (YB)	7	*Betula alleghaniensis* *Acer spicatum*
			Black cherry (BC)	7	*Prunus serotina* *Carya* spp.
			Green ash (GA)	12	*Fraxinus americana* *Quercus rubra*
			American basswood (AB)	9	*Tilia americana* *Fraxinus pennsylvanica*
			Black birch (BB)	11	*Betula lenta* *Acer pensylvanicum*
			American beech (BE)	13	*Fagus grandifolia* *Tilia americana*
Sugar maple (SM)	55	*Acer saccharum* *Magnolia acuminata* *Tilia americana*	Sugar maple (SM)	55	*Acer saccharum* *Magnolia acuminata* *Tilia americana*
Eastern hemlock (EH)	24	*Tsuga canadensis* *Betula* spp.	Eastern hemlock (EH)	24	*Tsuga canadensis* *Betula* spp.
Northern red oak (NRO)	70	*Quercus rubra* *Acer rubrum*	Northern red oak (NRO)	28	*Quercus rubra* *Acer saccharum* *Ostrya virginiana*
			Red maple (RM)	42	*Acer rubrum* *Quercus rubra*
Chestnut oak (CO)	64	*Quercus prinus* *Kalmia latifolia* *Acer rubrum*	Chestnut oak (CO)	64	*Quercus prinus* *Kalmia latifolia* *Acer rubrum*
White oak (WO)	33	*Quercus alba* *Pinus rigida* *Pinus strobus*	White oak (WO)	33	*Quercus alba* *Pinus rigida* *Pinus strobus*
Table mountain pine (TMP)	44	*Pinus pungens* *Pinus virginiana*	Table mountain pine (TMP)	5	*Pinus pungens* *Pinus virginiana* *Quercus prinus*
			Hickory (Hic)	21	*Carya* spp. *Quercus prinus* *Cornus floridana*
			White pine (WP)	18	*Pinus strobus* *Pinus virginiana* *Quercus prinus*

Notes: Habitats are arranged from the most mesic to the most xeric as determined by mean field capacity of sites grouped at low resolution. Intermediate-resolution groups were created by separating the low-resolution groups.

ticollinearity based upon collinearity statistics described in Myers (1990), use of individual variables was justified and should provide the most informative, ecologically interpretable models.

Statistical analyses

The distribution of voles among habitats and habitat factors indicative of vole presence or absence were determined using stepwise multiple logistic regression (Hosmer and Lemeshow 1989). Design variables were entered into the stepwise procedure except a reference group that represented the lowest suitability vole habitat (Hosmer and Lemeshow 1989). Variables (Table 1) were chosen for retention in the models using subjective interpretation of preliminary models in conjunction with the backwards selection method and the log-ratio selection criterion (Hosmer and Lemeshow 1989). The goodness-of-fit of each model was assessed using the Hosmer-Lemeshow test (Hosmer and Lemeshow 1989).

Factors indicative of vole abundance were identified using multiple linear regression, using only sites where voles were captured. Vole abundance was determined using the minimum-number-alive method (Krebs 1966); juveniles were excluded from analyses. Design variables were treated as described for multiple logistic regression. Final high-resolution models were generated using backwards stepwise multiple linear regression with conventional and relaxed selection criteria (Myers 1990). The relationship between R^2 and adjusted R^2 values was used to gauge the goodness-of-fit of multiple linear regression models, and prediction sums of squares (PRESS) statistics were utilized to select models with the greatest amount of predictive ability. Generally, the smaller the absolute value of the PRESS statistics, the more accurate the model (Myers 1990).

Preliminary statistical analyses, including t tests and regression analyses were executed using the SPSS advanced statistics software package (Norusis 1993) and the NCSS statistics package (Hintze 1998). Indicator species analysis (Dufrêne and Legendre 1997), cluster analysis, and DCA were performed using PC-ORD for WINDOWS software (McCune and Mefford 1995). Results were deemed statistically significant if $P \leq 0.05$.

Results

Trapping

A total of 6893 captures of small mammals was recorded during 25 550 trap-nights of effort between 12 May and 5 September 1996 and between 17 May and 5 September 1997. Twenty species were captured at least once; nine species composed 99% of the initial captures. There were 372 initial captures of *Clethrionomys gapperi* at 127 of the sample sites.

Number of voles per site was greatest in the summer (3.3 ± 0.4, mean ± 1 SE), followed by autumn (2.8 ± 0.9) and spring (2.5 ± 0.5). While the variation in vole abundance was not significant (ANOVA, $P = 0.39$), this should be interpreted cautiously because different habitats were sampled during these seasons.

Vole presence

Voles were distributed nonrandomly among habitats ($P < 0.001$). Vole presence or absence was predicted with 69.2% accuracy at low resolution, 67.5% accuracy at intermediate resolution, and 80.1% accuracy at high resolution (Table 3). All models significantly ($P < 0.001$) affected the determination of *Clethrionomys* presence within a site, and fit the data well as measured by the Hosmer-Lemeshow (1989) test of goodness of fit (Table 3).

At low resolution, *Clethrionomys* was most likely to be absent in white oak or table mountain pine stands. At intermediate resolution, *Clethrionomys* was most likely to be present in sugar maple (*Acer saccharum*), mixed mesophytic, eastern hemlock (*Tsuga canadensis*), American beech (*Fagus grandifolia),* and white ash (*Fraxinus americana*) stands. *Clethrionomys* was most likely to be absent from white oak (*Quercus alba*) stands at intermediate resolution.

Macrohabitats characterized by green ash (*Fraxinus pennsylvanica*), black cherry (*Prunus serotina*), and eastern hemlock (*Tsuga canadensis*) in the canopy and American hornbeam (*Carpinus caroliniana*) in the understory were most likely to contain *C. gapperi.* The probability of vole presence was least at very low or very high values of TRE61 (Table 3). Voles were also more likely to be present in habitats as ASPECT approached northwest, ELEV and FC increased, and ROCK2, ROCK4, and WDYDEB increased. Conversely, red-backed voles were least likely to be found in habitats characterized by high WOODSUM, ROCK1, and TRE1125 and coverage of *Vaccinium* spp. shrubs (Table 3).

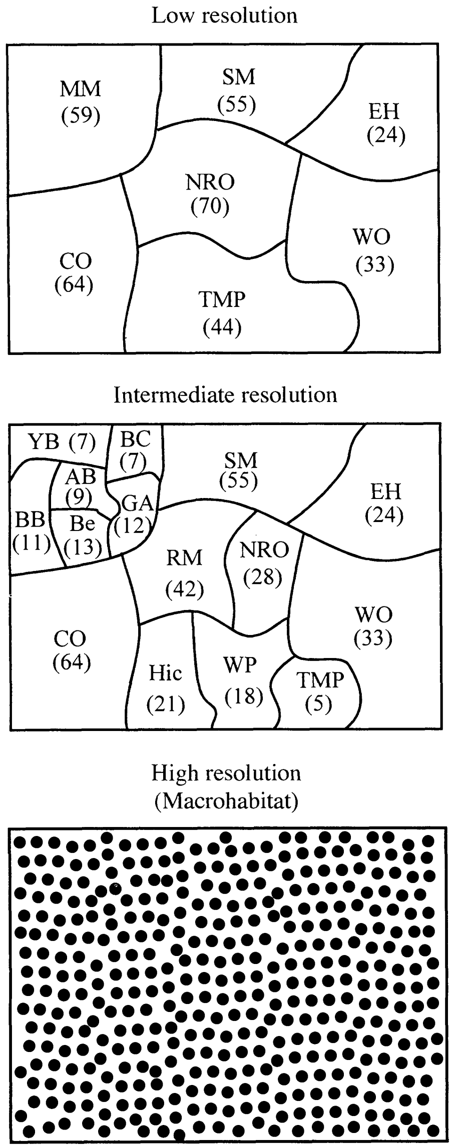


FIG. 1. Levels of resolution used in the analysis. Each square represents the 160-km² study area. The number of sites in each habitat type is indicated in parentheses. At low resolution, sites were classified into one of seven habitat types. At intermediate resolution, the seven low-resolution habitat types were further dissected, resulting in 15 habitat types. Note that some habitat types remained undivided, i.e., some habitat types were relatively homogenous. Habitat types are abbreviated using the initial letters of the common names as (see codes in Table 2). At high resolution, all sites ($N = 349$) were considered individually. Note that this figure is greatly simplified for clarity. In reality, habitat types were not one continuous patch as suggested by the low- and intermediate-resolution depictions. Rather, there were many replicates of each habitat type within the study landscape.

Vole abundance

The high-resolution multiple linear regression model accounted for the most variance in red-backed vole abundance at sample sites ($R^2 = 0.67$, $P < 0.001$; Table

TABLE 3. Summary of models predicting the presence and abundance of *Clethrionomys gapperi* in the southern Appalachians, USA, at several spatial scales using logistic regression.

			Model statistics			
Scale of prediction	Significant variables	Relationship	χ^2	P	Percentage correct	Goodness of fit
Low resolution	Mixed mesophytic	Linear (+)	50.3	<0.001	69.2	0.99
	Sugar maple	Linear (+)				
	Eastern hemlock	Linear (+)				
	Northern red oak	Linear (+)				
	Chestnut oak	Linear (+)				
Intermediate resolution	Yellow birch	Linear (+)	19.2	<0.001	67.5	0.99
	American beech	Linear (+)				
	Sugar maple	Linear (+)				
	Eastern hemlock	Linear (+)				
	White oak	Linear (−)				
Macrohabitat	American hornbeam	Linear (+)	129.4	<0.001	80.1	0.97
	Green ash	Linear (+)				
	Eastern hemlock	Linear (+)				
	Blueberry (shrub)	Linear (−)				
	TRE1125	Linear (−)				
	TRE61	Unimodal				
	ASPECT	Linear (+)				
	ELEV	Linear (+)				
	FC	Linear (+)				
	ROCK1	Linear (−)				
	ROCK2	Linear (+)				
	ROCK4	Linear (+)				
	WDYDEB	Linear (+)				
	WOODSUM	Linear (−)				

Notes: Variables were treated and selected as described in *Materials and Methods*. The number of sites used in the analysis was 349.

4). The intermediate-resolution model explained 23% of the variance in vole abundance ($R^2 = 0.23$, $P < 0.001$), followed by the low-resolution model ($R^2 = 0.09$, $P = 0.001$).

At low resolution, vole abundance increased as habitats resembled the mixed mesophytic stand type to a greater degree. Vole abundance increased as habitats more closely resembled the yellow birch, white ash, and American basswood stand types at intermediate resolution (Table 4). *Clethrionomys* abundance increased in macrohabitat comprised of *Betula alleghaniensis, Pinus rigida,* and *Prunus serotina* (Table 4). Vole abundance also increased as *Acer spicatum,* mountain laurel (*Kalmia latifolia*), and vines (*Lonicera* spp. and *Vitis* spp.) increased in the understory. *Clethrionomys* abundance increased with ELEV and ROCK3. Vole abundance decreased as TRE1125 increased.

TABLE 4. Summary of models predicting the presence and abundance of *Clethrionomys gapperi* in the southern Appalachians, USA, at various resolutions using multiple linear regression.

			Model statistics				
Scale of prediction	Significant variables	Relationship	F	P	R^2	Adjusted R^2	PRESS
Low resolution	Mixed mesophytic	Linear (+)	11	0.001	0.09	0.08	184.3
Intermediate resolution	Yellow birch	Linear (+)	11.5	<0.001	0.23	0.21	171.1
	Green ash	Linear (+)					
	American basswood	Linear (+)					
Macrohabitat	Striped maple (shrub)	Linear (+)	24.1	<0.001	0.67	0.64	132.7
	Yellow birch	Linear (+)					
	Mountain laurel	Linear (+)					
	Pitch pine	Linear (+)					
	Black cherry	Linear (+)					
	TRE1125	Linear (−)					
	VINES	Linear (+)					
	ELEV	Linear (+)					
	ROCK3	Linear (+)					

Notes: Variables were treated and selected as described in *Materials and Methods*. The number of sites used in the analysis was 127.

Discussion

Predicting vole presence and abundance

Distribution and abundance of red-backed voles were best predicted using the macrohabitat-scale models. *Clethrionomys* utilized and selected from a relatively discrete portion of the complex landscape, evidenced by decreased accuracy as landscape groups became less resolute (Tables 3 and 4). At the low and intermediate resolutions, habitats viewed as homogenous are composed of an array of habitat patches too heterogeneous at high resolution to accurately predict vole presence or abundance (Fig. 1). This is not surprising considering the large geographic area of the study landscape and the degree of variability introduced by substrate gradients, elevation gradients, and hydrologic interactions.

Large-scale habitat classifications based upon satellite imagery and GIS technology may be useful for predicting habitats suitable for red-backed voles. While large-scale classifications are not useful for predicting *C. gapperi* abundance, such classifications may identify suitable habitats that would be good candidates for macrohabitat-scale investigation. Additionally, macrohabitat data useful for predicting vole abundance can be gathered with a minimal investment of field time, as plant communities and site attributes are relatively easy to quantify. In this manner, managers can assess habitats in a hierarchical manner and can identify areas of concern in a relatively efficient manner. Use of low-resolution classifications may be effective for predicting suitable and quality habitats for generalist small mammal species, such as *Peromyscus* species (Adler and Wilson 1987), which operate at a coarser grain than do specialists (Kolasa 1990). Species of special concern in the region, such as the rock vole (Pagels 1990), water shrew (Pagels and Tate 1976), and northern flying squirrel (Payne et al. 1989), are often associated with habitats where voles are abundant and that are likely to elude low-resolution models. In this regard, the accuracy with which suitable vole habitat can be located supports the utility of *C. gapperi* as a potential indicator species (Nordyke and Buskirk 1988) for locating habitat suitable for these rare species. As technology allows the creation of more resolute classification schemes, managers and modelers alike may be able to better understand how species view and interact with the landscape.

Patterns of vole distribution

Vole presence and abundance were characterized by abiotic and biotic indicators of water availability and high levels of moisture at all scales examined. The physiological basis for selection of moist habitats lies in the dilute urine produced by *C. gapperi* that increases water requirements to between twice (Getz 1968) and nearly ten times (Odum 1944) that of other small mammals such as white-footed mice (*Peromyscus leucopus*) and deer mice (*P. maniculatus*). Downed woody debris provides sheltered runway areas (Miller and Getz 1973, Tallmon and Mills 1994) and provides moist microsites and substrates, favoring growth of hypogeal fungi often consumed by *Clethrionomys gapperi* (Maser et al. 1978, Clarkson and Mills 1994, Waters et al. 1997). The finding that suitability is positively associated with downed woody debris, but negatively associated with the quantity of large (>10 cm) downed woody debris, may reflect the more heterogeneous substrate provided by an abundance of small twigs and branches. Rocky areas provide much-needed components of vertical and horizontal cover that allow *C. gapperi* to avoid capture by predators (Wywialowski 1987) (in light of their poor climbing ability [Getz and Ginsberg 1968] and relatively slow ground speed [Layne and Benson 1954]), and may offer preferred nesting areas (Wywialowski 1987, Stewart 1991). Rocky, talus slopes maintain a thermally stable environment (Hack and Goodlett 1960), moist substrates are more thermally stable (Hack and Goodlett 1960), and suitable vole habitat is characterized by increased cover and an aspect that minimizes solar irradiance.

Requirements for suitable vole habitat provide a characterization of the niche utilized by *C. gapperi* and are similar to the findings of Steblein (1984). Suitable macrohabitats are mesic habitats at moderate elevation with complex substrates. Once these conditions are met, vole abundance increases as elevation increases and evergreen shrub cover (mountain laurel) increases. It is likely that evergreen shrub cover may consistently reduce predation pressure on voles, which are active all year (Merritt 1981). Additionally, the presence of an evergreen shrub layer may also contribute to a sheltered, thermally stable microclimate during temperate seasons. The increase in vole abundance with elevation reflects the ecological conditions under which *C. gapperi* evolved (Guilday 1971).

Implications for habitat selection

Couch (1998) found that voles are not dispersal limited in the southern Appalachians, suggesting that macrohabitat selection is the primary factor constraining vole distribution in the study area, i.e., voles discriminate among habitat patches at this scale (Morris 1987*a*). The efficacy of the high-resolution models suggests that the functional grain (degree of patchiness) at which voles perceive habitat (Kotliar and Wiens 1990) is at the macrohabitat scale. Because habitats were not assessed at a more resolute scale, it is unknown whether voles select habitat at a more resolute grain, although results of this study and those by Morris (1996) and Knight and Morris (1996) suggest not. While the degree to which vole movement is altered by landscape characteristics (Buechner 1989, Dunning et al. 1992, Anderson and Danielson 1997) is unknown, the association of voles with specific macrohabitat features suggests that voles have access to all habitats within the study area, perhaps with the exception of low-elevation habitats. The increasing ability to predict suitable vole habitat with increasing resolution suggests that voles moving across the landscape of the southern Appalachians utilize hierarchical habitat selection (Kotliar and Wiens 1990), although this hypothesis was not specifically tested.

Vole habitat in the study region was composed of relatively distinct ecological conditions at the macrohabitat scale, and vole abundance was related with habitat variables at that scale. When interpreting a landscape, managers must consider changes in patches at high resolution to predict population-level impacts of management on *C. gapperi.* Alteration of macrohabitat is likely to alter population structure, even if dispersal allows colonization of disturbed habitats. Smaller patches of suitable macrohabitat would support smaller populations of *C. gapperi,* with implications that follow from island biogeography theory (MacArthur and Wilson 1967), such as increased probability of local extinction, loss of heterozygosity (Loxterman et al. 1998), and decreased resistance to environmental change (Via and Lande 1985). Landscape effects would include decreased fitness due to increased costs of foraging both in time and increased predation risk (Morris 1987*b*). While the degree to which metapopulation dynamics apply to *C. gapperi* is unknown, macrohabitat size and availability certainly should be considered in this context as well (Hanski and Gilpin 1997). Our research indicates that macrohabitat integrity is essential for vole abundance among a wide variety of habitat types, although abundance also responds to intermediate-resolution variation to a lesser degree. Because habitats with abundant *C. gapperi* often contain a diverse assemblage of small mammals (Pagels et al. 1994), alteration of such habitats may also have serious effects on rare macrohabitat specialists, especially isolated populations (Pagels 1990) and vertebrates of limited dispersal ability (Mitchell et al. 1997).

It is likely that voles exploit different portions of the macrohabitat, if only because resource requirements, predation risk, and social status vary with sex and age (Nordahl and Korpimäki 1998). It is also possible that the scales of habitat use and selection vary among individuals of different sex and age, i.e., perception of opportunities and subsequent selection may be a function of each vole's position in the social hierarchy (Mihok 1979, Bondrup-Nielsen 1987). While our work has identified factors associated with vole presence and abundance, a profitable next step would be to follow cohorts of voles within various habitats in manipulated landscapes to clarify the roles of demographic status, age, habitat quality, and landscape structure in affecting habitat selection by the individual.

Clethrionomys gapperi exhibits macrohabitat selection across a wide geographic range (this study, Knight and Morris 1996, Morris 1996) within a variety of forest types and treatments, providing a framework for understanding how vole populations should be investigated (Morris 1987*a*, Wiens et al. 1987, Dunning et al. 1992). Vole presence and abundance were best predicted at the macrohabitat scale, although presence was also predictable at larger scales of analysis. *Clethrionomys* was associated with specific tree and shrub communities indicative of mesic soil conditions with high field capacity and complex, heterogeneous substrates of rocky talus, woody debris, and cover. Voles were abundant in habitats containing the most complex substrates and poorly drained soils, with an aspect that minimized solar load and reduced thermally induced water stress. Although they may satisfactorily identify areas where voles are present, satellite-imaging systems currently lack the resolution to characterize habitats at a scale fine enough to predict vole abundance within habitats. Therefore, such systems are also limited in their ability to identify areas of habitat in which rare small mammal specialists in the region are often found. The incorporation of macrohabitat-scale forest community patterns with satellite imagery to create spatially explicit models is a promising avenue for bridging the gap between the large-grained scale at which management best operates and the scale at which small mammal distributions are regulated.

Acknowledgments

This study was supported in part by funds from the United States Forest Service for the Allegheny Mountain Project to Virginia Commonwealth University and the Conservation and Research Center of the Smithsonian Institution. We thank the staff at the Warm Springs Ranger Station in Warm Springs, Virginia, especially District Ranger Teri Raml and biologists Steve Tanqueray and Terry Flaherty. The study benefited from the help of numerous individuals from VCU, the CRC, Earthwatch volunteers, and residents around the study area in Mountain Grove, Virginia and Frost, West Virginia. We are grateful to D. Young, VCU, for extensive discussion of logistic considerations and for the helpful suggestions of two anonymous reviewers. The staff at Virginia Power's Bath County Pumped Storage Hydroelectric Facility, especially biologist Sarah Bell, provided access to several sampling sites and climatological data.

Literature Cited

Adler, G. H., and M. L. Wilson. 1987. Demography of a habitat generalist, the white-footed mouse, in a heterogeneous environment. Ecology **68**:1785–1796.

Anderson, G. S., and B. J. Danielson. 1997. The effects of landscape composition and physiognomy on metapopulation size: the role of corridors. Landscape Ecology **12**:261–271.

Beers, T. W., P. E. Dress, and L. C. Wensel. 1966. Aspect transformation in site productivity research. Forestry **64**:691–692.

Bondrup-Nielsen, S. 1987. Demography of *Clethrionomys gapperi* in different habitats. Canadian Journal of Zoology **65**:277–283.

Bowers, M. A., and S. F. Matter. 1997. Landscape ecology of mammals: relationships between density and patch size. Journal of Mammalogy **78**:999–1013.

Buechner, M. 1989. Are small-scale landscape features important factors for field studies of small mammal dispersal sinks? Landscape Ecology **2**:191–199.

Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. Journal of Wildlife Management **39**:388–394.

Clarkson, D. A., and L. S. Mills. 1994. Hypogeous sporocarps in forest remnants and clearcuts in southwest Oregon. Northwest Science **68**:259–265.

Couch, C. R. 1998. Vicariance and genetic structuring in relict populations of the red-backed vole, *Clethrionomys gapperi,* in Virginia. Thesis. Virginia Commonwealth University, Richmond, Virginia, USA.

Dufrêne, M., and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs **67**:345–366.

Dunning, J. B., Jr., B. J. Danielson, and H. R. Pulliam. 1992. Ecological processes that affect populations in complex landscapes. Oikos **65**:169–175.

Dunning, J. B., Jr., D. J. Stewart, B. J. Danielson, T. L. Root, R. H. Lamberson, and E. E. Stevens. 1995. Spatially explicit population models: current forms and future uses. Ecological Applications **5**:3–11.

Eyre, F. H. 1980. Forest cover types of the eastern U. S. and Canada. Society of American Foresters, Washington, D.C., USA.

Fisher, R. L. 1968. An ecological study of the red-backed vole, *Clethrionomys gapperi gapperi* (Vigors), in central New York. Dissertation. Cornell University, Ithaca, New York, USA.

Fox, J. 1991. Regression diagnostics. Sage, London, UK.

Getz, L. L. 1968. Influence of water balance and microclimate on the local distribution of the redback vole and white-footed mouse. Ecology **49**:276–285.

Getz, L. L., and V. Ginsberg. 1968. Arboreal behavior of the red-backed vole, *Clethrionomys gapperi.* Animal Behavior **16**:418–424.

Guilday, E. F. 1971. The Pleistocene history of the Appalachian mammal fauna. Pages 233–262 *in* P. C. Holt, editor. The distributional history of the biota of the southern Appalachians. Part III: Vertebrates. Research Division Monograph 4. Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA.

Hack, J. T., and J. C. Goodlett. 1960. Geomorphology and forest ecology of a mountain region in the central Appalachians. United States Geological Survey Professional Paper **347**:1–66.

Handley, C. O., Jr. 1971. Appalachian mammalian geography—recent epoch. Pages 263–303 *in* P. C. Holt, editor. The distributional history of the biota of the southern Appalachians. Part III: Vertebrates. Research Division Monograph 4. Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA.

Handley, C. O., Jr., and E. K. V. Kalko. 1993. A short history of pitfall trapping in America, with a review of methods currently used for small mammals. Virginia Journal of Science **44**:19–26.

Hanski, I., and M. E. Gilpin. 1997. Metapopulation biology: ecology, genetics, and evolution. Academic Press, San Diego, California, USA.

He, H. S., D. J. Mladenoff, V. C. Radeloff, and T. R. Crow. 1998. Integration of GIS data and classified satellite imagery for regional forest assessment. Ecological Applications **8**:1072–1083.

Hintze, J. 1998. NCSS (Number Cruncher Statistical Software) 2000. NCSS, Keysville, Utah, USA.

Hosmer, D. W., Jr., and S. Lemeshow. 1989. Applied logistic regression. Wiley, New York, New York, USA.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology **61**:65–71.

Jongman, R. H. G., C. J. F. ter Braak, and O. F. R. Van Tongeren, editors. 1995. Data analysis in community and landscape ecology. Cambridge University Press, Cambridge, UK.

Kirkland, G. L., Jr. 1990. Patterns of initial small mammal community change after clearcutting of temperate North American forests. Oikos **59**:313–320.

Knight, T. W., and D. W. Morris. 1996. How many habitats do landscapes contain? Ecology **77**:1756–1764.

Kolasa, J. 1990. Ecological systems in hierarchical perspective: breaks in community structure and other consequences. Ecology **70**:36–47.

Kotliar, N. B., and J. A. Wiens. 1990. Multiple scales of patchiness and patch structure: a hierarchical framework for the study of heterogeneity. Oikos **59**:253–260.

Krebs, C. J. 1966. Demographic changes in fluctuating populations of *Microtus californicus.* Ecological Monographs **36**:239–273.

LaBarbera, M. 1989. Analyzing body size as a factor in ecology and evolution. Pages 97–118 *in* R. F. Johnston, P. W. Frank, and C. D. Michener, editors. Annual review of ecology and systematics. Annual Reviews, Palo Alto, California, USA.

Lance, G. N., and W. T. Williams. 1967. A general theory of classificatory sorting strategies. I. Hierarchical systems. Computer Journal **9**:373–380.

Layne, J. N., and A. H. Benson. 1954. Some speeds of small mammals. Journal of Mammalogy **35**:103–104.

Levin, S. A. 1992. The problem of pattern and scale in ecology. Ecology **73**:1943–1967.

Loxterman, J. L., N. D. Moncrief, R. D. Dueser, C. R. Carlson, and J. F. Pagels. 1998. Dispersal abilities and genetic population structure of insular and mainland *Oryzomys palustris* and *Peromyscus leucopus.* Journal of Mammalogy **79**:66–77.

MacArthur, R. H., and E. O. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton, New Jersey, USA.

Maser, C., J. M. Trappe, and R. A. Nussbaum. 1978. Fungal-small mammal interrelationships with emphasis on Oregon coniferous forests. Ecology **59**:799–809.

McCune, B., and M. J. Mefford. 1995. PC-ORD. Multivariate analysis of ecological data. Version 2. MjM Software Design, Gleneden Beach, Oregon, USA.

Merritt, J. F. 1981. *Clethrionomys gapperi.* Mammalian Species **146**:1–9.

Mihok, S. 1979. Behavioral structure and demography of subarctic *Clethrionomys gapperi* and *Peromyscus maniculatus.* Canadian Journal of Zoology **57**:1520–1535.

Miller, D. H. 1970. An analysis of the local distribution of the redback vole, *Clethrionomys gapperi* (Vigors) in northern Vermont and central Connecticut. Dissertation. University of Connecticut, Storrs, Connecticut, USA.

Miller, D. H., and L. L. Getz. 1973. Factors influencing the local distribution of the redback vole, *Clethrionomys gapperi,* in New England. II. Vegetation cover, soil moisture, and debris cover. University of Connecticut Occasional Papers **2**:159–180.

Mitchell, J. C., S. C. Rinehart, J. F. Pagels, K. A. Buhlmann, and C. A. Pague. 1997. Factors influencing amphibian and small mammal assemblages in central Appalachians forests. Forest Ecology and Management **96**:65–76.

Morris, D. W. 1984. Patterns and scale of habitat use in two temperate-zone, small mammal faunas. Canadian Journal of Zoology **62**:1540–1547.

Morris, D. W. 1987*a*. Ecological scale and habitat use. Ecology **68**:362–369.

Morris, D. W. 1987*b*. Spatial scale and the cost of density-dependent habitat selection. Evolutionary Ecology **1**:379–388.

Morris, D. W. 1989. The effect of spatial scale on patterns of habitat use: red-backed voles as an empirical model of local abundance for northern mammals. Pages 23–32 *in* D. W. Morris, Z. Abramsky, B. J. Fox, and M. R. Willig, editors. Patterns in the structure of mammalian communities. Texas Tech University Press, Lubbock, Texas, USA.

Morris, D. W. 1996. Coexistence of specialist and generalist rodents via habitat selection. Ecology **77**:2352–2364.

Myers, R. H. 1990. Modern regression with applications. Second edition. Duxbery, Belmont, California, USA.

Nordahl, K., and E. Korpimäki. 1998. Does mobility or sex of voles affect risk of predation by mammalian predators? Ecology **79**:226–232.

Nordyke, K. A., and S. W. Buskirk. 1988. Evaluation of small mammals as ecological indicators of old-growth conditions. Pages 353–358 *in* R. C. Szaro, K. E. Severson, and D. R. Patton, technical coordinators. Management of amphibians, reptiles, and small mammals in North America. U.S. Forest Service General Technical Report **RM-166**.

Norusis, M. J. 1993. SPSS for Windows advanced statistics. Release 6.0. SPSS, Chicago, Illinois, USA.

Odum, E. P. 1944. Water consumption of certain mice in relation to habitat selection. Journal of Mammalogy **25**: 404–405.

Pagels, J. F. 1990. First record of the rock vole, *Microtus chrotorrhinus* (Miller)(Rodentia: Cricetidae), in Virginia. Brimleyana **16**:1–3.

Pagels, J. F., and C. M. Tate. 1976. Shrews (Insectivora: Soricidae) of the Paddy Knob-Little Back Creek area of western Virginia. Virginia Journal of Science **27**:202–203.

Pagels, J. F., K. L. Uthus, and H. E. Duval. 1994. The masked shrew, *Sorex cinereus,* in a relictual habitat of the southern Appalachian mountains. Pages 103–109 *in* J. F. Merritt, G. L. Kirkland, Jr., and R. K. Rose, editors. Advances in the biology of shrews. Carnegie Museum of Natural History Special Publication Number 18, Pittsburgh, Pennsylvania, USA.

Payne, J. L., D. R. Young, and J. F. Pagels. 1989. Plant community characteristics associated with the endangered northern flying squirrel, *Glaucomys sabrinus,* in the southern Appalachians. American Midland Naturalist **121**:285–292.

Pulliam, H. R., and B. J. Danielson. 1991. Sources, sinks, and habitat selection: a landscape perspective on population dynamics. American Naturalist **137**:S50–S66.

Pulliam, H. R., J. Liu, J. B. Dunning, Jr., D. J. Stewart, and T. D. Bishop. 1994. Modelling animal populations in changing landscapes. Ibis **137**:S120–S126.

Salter, P. J., and J. B. Williams. 1967. The influence of texture on the moisture characteristics of soils. IV. A method of estimating the available-water capacities of profiles in the field. Journal of Soil Science **18**:174–181.

Stapp, P. 1997. Habitat selection by an insectivorous rodent: patterns and mechanisms across multiple scales. Journal of Mammalogy **78**:1128–1143.

Steblein, P. F. 1984. Niche-habitat relationships of red-backed vole, *Clethrionomys gapperi* (Vigors) from New York and Pennsylvania. Thesis. Shippensburg University, Shippensburg, Pennsylvania, USA.

Stewart, C. A. 1991. A note on the microdistribution of the red-backed vole, *Clethrionomys gapperi* in the E. N. Huyck Preserve, New York, USA. Canadian Field-Naturalist **105**: 274–275.

Tallmon, D., and L. S. Mills. 1994. Use of logs within home ranges of California red-backed voles on a remnant forest. Journal of Mammalogy **75**:97–101.

Thomas, D. L., and E. J. Taylor. 1990. Study designs and tests for comparing resource use and availability. Journal of Wildlife Management **54**:322–330.

Turner, M. G., G. J. Arthaud, R. T. Engstrom, S. J. Heil, J. Liu, S. Loeb, and K. S. McKelvey. 1995. Usefulness of spatially explicit population models in land management. Ecological Applications **5**:12–16.

Via, S., and R. Lande. 1985. Genotype-environment interaction and the evolution of phenotypic plasticity. Evolution **39**:505–522.

Waters, J. R., K. S. McKelvey, D. L. Luoma, and C. J. Zabel. 1997. Truffle production in old-growth and mature fir stands in northeastern California. Forest Ecology and Management **96**:155–166.

Wiens, J. A., J. T. Rotenberry, and B. Van Horne. 1987. Habitat occupancy patterns of North American shrubsteppe birds: the effects of spatial scale. Oikos **48**:132–147.

Wiser, S. K., R. K. Peet, and P. S. White. 1998. Prediction of rare-plant occurrence: a southern Appalachian example. Ecological Applications **8**:909–920.

Wywialowski, A. P. 1987. Habitat structure and predators: choices and consequences for rodent habitat specialists and generalists. Oecologia **72**:39–45.

Zar, J. H. 1996. Biostatistical analysis. Third edition. Prentice-Hall, Upper Saddle River, New Jersey, USA.

Great Trinity Forest Management Plan

Wildlife Management

Texas Fresh Water Fish

Texas Fresh Water Fish

Black Basses

- Largemouth bass
- Smallmouth bass
- Spotted bass
- Guadalupe bass

True Basses

- White bass
- Yellow bass
- Striped bass
- Hybrid striped bass

Catfish and Bullheads

- Blue catfish
- Channel catfish
- Flathead catfish
- Black bullhead
- Yellow bullhead

Crappie

- Black crappie
- White crappie

Sunfishes

- Bluegill
- Green sunfish
- Longear sunfish
- Redbreast sunfish

- Redear sunfish
- Warmouth

Carp and Minnows

- Common carp
- Grass carp
- Texas shiner
- Golden shiner
- Blacktail shiner
- Red shiner
- Fathead minnow

Gar

- Alligator gar
- Longnose gar
- Shortnose gar
- Spotted gar

Suckers

- Bigmouth buffalo
- Black buffalo
- Smallmouth buffalo

Other Fishes

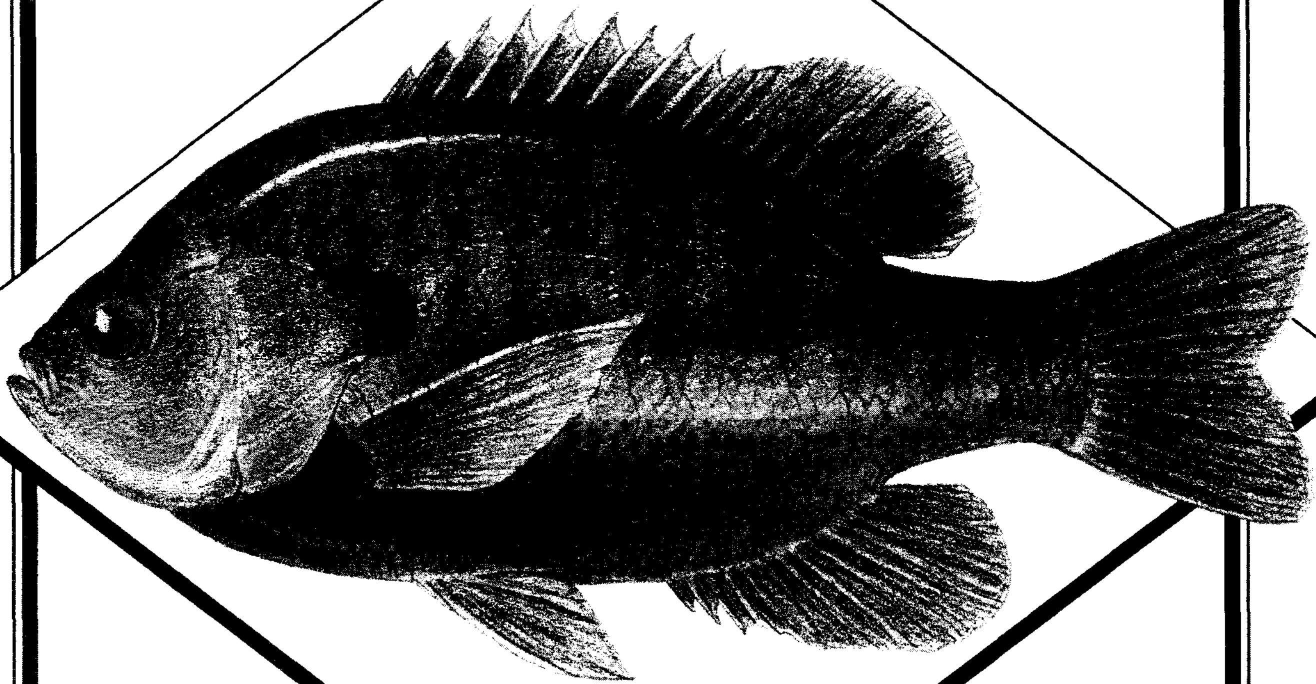
- American eel
- Bowfin
- Chain pickerel
- Freshwater drum
- Red drum
- Paddlefish
- Rainbow trout
- Rio Grande cichlid

- Gizzard shad
- Threadfin shad
- Walleye

B-213

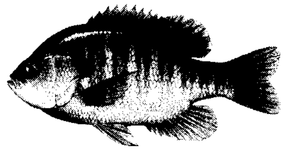
Texas Agricultural Extension Service

Management of Recreational Fish Ponds in Texas



Joe T. Lock, Associate Professor
and Extension Fisheries Specialist
The Texas A&M University System

Texas Agricultural Extension Service • Zerle L. Carpenter, Director
The Texas A&M University System • College Station, Texas



Texas has more than 800,000 private ponds. Ponds are usually built for several purposes: irrigation, livestock watering and recreation. Recreation is probably the most important reason for building a pond in Texas. Unfortunately, most ponds are poorly managed for recreation, even though as much as 25 percent of all fishing takes place in private ponds.

Properly managed ponds provide excellent recreational opportunities. A good fishing pond must be managed like a vegetable garden: It must be seeded (or stocked) properly, limed and fertilized correctly, weeded now and then, and harvested in the correct numbers and on an appropriate timetable.

The purpose of this publication is to provide the owner or manager with guidelines for correct pond management.

The first step in recreational pond management is to decide what kind of recreation is desired. Ponds can be managed for fishing, swimming, wildlife attraction and aesthetics. It is difficult to manage for all of these recreational activities equally well, but the most important can be emphasized. This publication will target fishing and attracting wildlife.

Pond Dynamics

No two ponds are ever exactly alike. Even ponds in the same watershed and built very close to each other can be very different in appearance, and differences in watershed and soil characteristics are particular to each pond. Differences affecting management are those associated with water quality, plankton and fish populations.

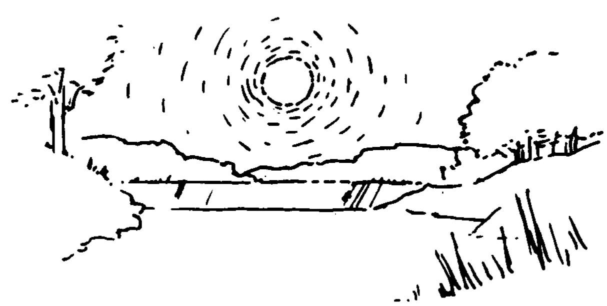
Water Quality

Water quality factors such as temperature, pH, alkalinity, hardness and dissolved oxygen affect fish health and production. These factors are rarely constant in a pond. Temperature, dissolved oxygen and pH will change or cycle each day and alkalinity can change over longer periods of time.

Oxygen Cycle

Oxygen is dissolved in water from two sources–air and photosynthesis. Oxygen dissolves into the pond water from the air as the two are mixed together through wind and wave action. Mechanical aeration using pumps, sprayers and paddlewheels can be used to increase dissolved oxygen levels during periods of low oxygen.

Photosynthesis is the other source of dissolved oxygen. In this process, plants produce oxygen while making food from carbon dioxide and water in the presence of sunlight. Algae release this oxygen directly into the water during photosynthesis. Since photosynthesis is driven by the energy of sunlight, oxygen production occurs during daylight. Therefore, dissolved oxygen concentrations in ponds tend to rise throughout the day. At night dissolved oxygen slowly declines as fish, insects, zooplankton, bacteria and algae consume oxygen through respiration. Under normal conditions dissolved oxygen concentrations should not fall below 3 or 4 parts per million (ppm). Oxygen concentrations below 3 ppm stress fish and many fish will suffocate at concentrations below 2 ppm.



Alkalinity, Hardness, and pH

Alkalinity and hardness are important in providing adequate natural food and in maintaining a healthy fish population. The pH of the pond cycles daily because of respiration and photosynthesis. Carbon dioxide released from respiration reacts with water, producing carbonic acid. The pH scale measures the acidity; therefore, as carbonic acid is formed the pH is lowered or the pond becomes temporarily more acidic. Algae use carbon dioxide for photosynthesis during daylight hours and the pond water becomes less acidic with the decline of carbonic acid. Because of this, a pond pH normally fluctuates between 6.5 and 9. If the pH drops below 5, as it does in ponds that receive acid runoff, or rises above 10, as in low alkalinity ponds with excessive algae blooms, fish will be stressed and can die. The only practical method to manage for abnormal pH changes is to increase the alkalinity of the pond.

Alkalinity is a measure of bases in the water. Bases react to neutralize acids and, therefore, directly influence pH. As bases react with the hydrogen ions present, they buffer or suppress pH changes. Some alkalinity is necessary for good algae production. An alkalinity of 20 ppm or more is necessary for proper algae growth and, therefore, good fish production.

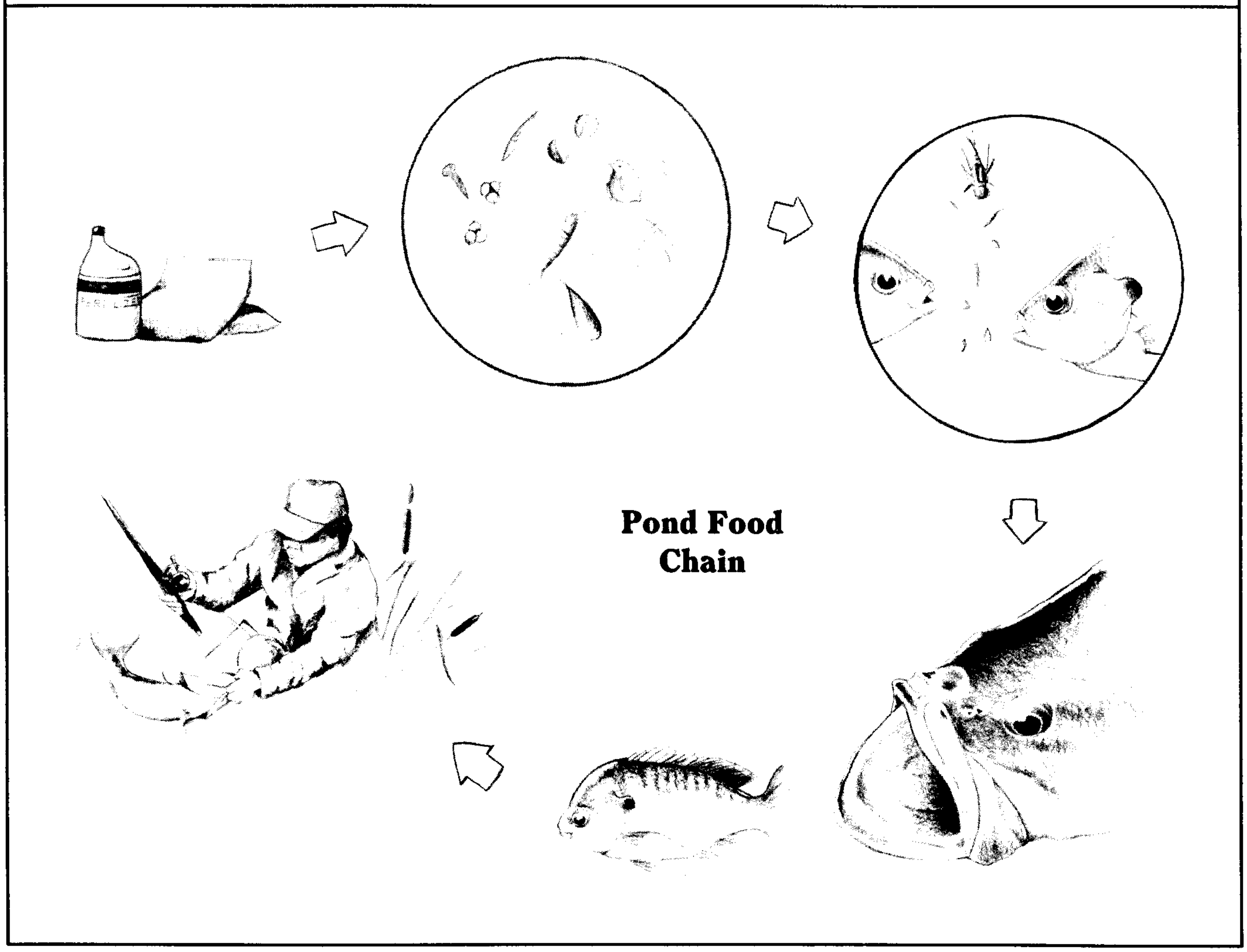
Hardness is a measure of calcium and magnesium ions. Hardness concentrations are usually similar to alkalinity (if derived from limestone) but can be different, especially in coastal areas. A lack of hardness can reduce plankton production and cause muddiness.

Blooms and Pond Color

Plankton is a term used for all microscopic and near microscopic living things that float in the water. Plankton includes both tiny aquatic plants called phytoplankton or algae, and animals called zooplankton. Planktonic algae serve as the base of the food chain. Zooplankton and aquatic insects feed on algae, and they in turn are eaten by small fish (fry). Small fish are then eaten by larger fish (Figure 1). Directly or indirectly, algae provide almost all the basic food for the pond except for a small quantity of insects and worms that fall or wash into the pond. Managing planktonic algae is essential in providing the food to produce an abundant and healthy fish population.

Changes in pond water color can be related to planktonic algae concentrations, called "blooms," or to suspended sediments and organic matter. Water which is good for fish production is green; the green color comes from billions of suspended microscopic algae. Water color changes if these algae blooms "die-off" rapidly, turning the water brown,

Figure1. Pond food chain from fertilizer to fishing.



black, milky or clear. When this happens, decomposition of the dead algae consumes oxygen, leading to possible stress, suffocation or disease in fish. Algae die-offs are common in deep ponds or in fish ponds receiving too many nutrients. Mechanical aeration may be necessary after algae die-offs to keep fish alive.

Sediments washed into ponds after heavy rains will also change pond color. Color should return to normal within a few days as settling occurs. Heavy sediment loads can stress fish by irritating the gills and reducing oxygen production. Ponds that receive sediments from surrounding fields may need a wide sod strip around the pond to help trap the sediments before they enter the pond (see Pond Construction). Bare pond banks should be covered with hay to establish sod and reduce erosion. A pond that receives sediment only during heavy rains may need a diversion ditch built around it to channel excess water away from the pond. Many chronically muddy ponds need lime to reduce acidity and to settle suspended clay. If your pond is always muddy, contact your county Extension office for help. The office is listed under your county name in the telephone book.

Essential Ingredients of Pond Management

Even though ponds are never exactly alike, all can be managed for fishing. The basic guidelines for good pond management will increase pond productivity and decrease problems. The guidelines are discussed in the following sections:

1. Pond construction and watershed management.
2. Species selection and stocking.
3. Removal of unwanted and overpopulated species of fish.
4. Liming and fertilization.
5. Harvesting and record keeping.
6. Pond balance management.
7. Weed control.

Pond Construction and Watershed Management

Poorly constructed ponds are always difficult to manage. Water levels may fluctuate radically because of pond seepage or inadequate watershed (area that drains rainfall into the pond), or both of these conditions. Aquatic weeds may grow rapidly in shallow areas. Erosion and contamination from the watershed may make good management impossible. For assistance in pond construction or renovation, contact your local USDA Soil Conservation Service (SCS) Office. The SCS can provide assistance in design, layout and monitoring construction of ponds.

All ponds should be designed and maintained with the following guidelines:

- The dam should have a compacted clay core.
- Soil lining the pond should be a minimum of 30 percent clay.
- Pond size should be matched to watershed area.
- Banks should slope rapidly to a depth of at least 2.5 feet.
- Drains and overflow pipes should be built through the dam.
- An emergency spillway should be constructed for periods of heavy run-off.

Pond leaks caused by poor construction are common. Pond dams must be constructed with a compacted clay core that is trenched into an impervious soil or rock layer below the pond bottom. Trees or other woody vegetation should never be allowed to grow on the dam, because roots will eventually penetrate the core and cause the pond to leak. Drains allow water levels to be regulated for better control of weeds and fish populations, and for easy access to repair or renovate the pond.

Texas ponds generally need 4 to 100 acres of watershed per acre-foot of pond storage. More watershed is required in West Texas and less in East Texas. Soil types, slope and vegetation covering the watershed will affect run-off. Generally, more area is needed if the watershed is wooded than if it is open. If the watershed is too large, a diversion ditch around the pond may be needed to keep the pond from flushing too rapidly.

Aquatic weed growth occurs most easily in shallow water. Pond banks should slope rapidly (2:1 or 3:1 ratio) to a depth of 2.5 feet or more. Aquatic plants do not easily establish themselves at this depth, especially if a good algae bloom is maintained (see Fertilization).

Fields next to ponds should have sod borders. Sod or grass strips 50 to 100 feet wide between the field and the pond reduce soil erosion and pesticide contamination that can kill fish.

Cutting a trench for the clay core of the pond dam.

Species Selection and Stocking

The choice of fish to stock depends on the pond owner's goals and on the resources available. It is very difficult to manage a pond of less than 1 acre for bass and bluegill. If your pond is less than 1 acre, catfish is probably your best choice. See Extension publication B-1319, "Catfish in Farm Ponds," for more detailed information.

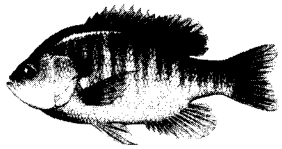
The most common stocking strategy is to combine largemouth bass and bluegill (or largemouth bass, bluegill and redear sunfish). The combination generally works well in ponds larger than 1 acre and provides excellent fishing for both species indefinitely.

The beauty of the bass and bluegill system is its simplicity. In a well-fertilized pond, zooplankton and insect larvae will be plentiful enough to supply food for bass fry and all sizes of bluegill. The bluegill will reproduce and grow rapidly with the abundant food and provide excellent forage (food) for the bass. If bass are not over-harvested, they will keep the bluegill from overpopulating. Some large bluegill will survive bass predation to provide good bluegill angling.

Channel catfish may also be added to a bass and bluegill pond, but the catfish will consume a portion of the food supply, slightly reducing the total pounds of bass and bluegill the pond can maintain.

Recommended stocking rates in Texas vary with the size, location and condition of the pond and the desires of the pond owner. See "Stocking and Management Recommendations for Texas Farm Ponds," Special Publication No. 1 of the Texas Chapter of the American Fisheries Society, to determine the number and species to stock. The publication is available from the Texas Agricultural Extension Service, Texas Parks and Wildlife Department and USDA Soil Conservation Service. A typical pond larger than 1 acre that will be fertilized should be stocked with 1,000 bluegill fingerlings (or 60 adults), 100 largemouth bass and 100 channel catfish per acre.

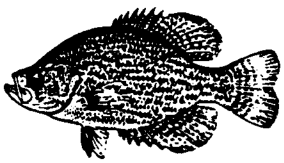
Bass, forage fishes and catfish for stocking new or renovated ponds can be obtained from private hatcheries. Private hatcheries will deliver directly to ponds and can provide fish at almost any time of the year. Many offer varieties or hybrids that have been selected for rapid



growth. Contact your county Extension office for lists of private hatcheries that sell fish in Texas.

Stocking of 3- to 5-inch bluegill is most often done in the fall or early winter. The bluegill will grow and spawn by the following spring. Bass are stocked in late May or June and grow rapidly, feeding on the new bluegill fry. Bluegill will spawn two or three more times before fall, providing adequate forage for the bass. Bass growth should average 1/4 to 1/2 pound in the first year and can approach 2 pounds if forage is plentiful. Catfish can be stocked in fall or spring. If stocked together always stock catfish as large or larger than the bass. Catfish usually cannot successfully reproduce in ponds with bass and bluegill populations and will have to be restocked as they are fished out.

Species that should not be stocked into farm ponds or should be stocked only under certain conditions include crappie, flathead catfish, common carp and green sunfish.



Black Crappie

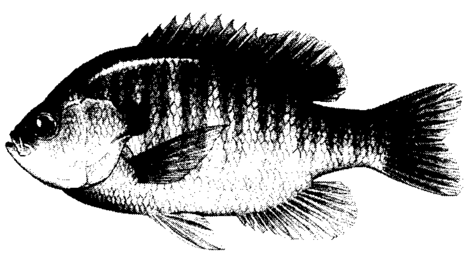
Crappie (both black and white) may pose management problems in small ponds in that they overpopulate and become stunted at sizes too small to be harvested. Under these conditions they compete with both bass and bluegill for food. Crappie can be stocked in larger farm ponds (more than 25 acres), but only after the largemouth bass initially stocked have spawned several times. Also, largemouth bass harvest must be carefully controlled to ensure enough bass in the pond to control crappie numbers.

Flathead catfish are voracious eaters, cannibalistic, and grow large enough to prey on even large bass. Other species that should not be stocked into farm ponds are common carp and bullhead catfish. Common carp can overpopulate rapidly, eat eggs of other fish, compete for food and muddy the pond through their bottom feeding activity. These species also compete for the available food resources and that can affect the survival of desirable fish.

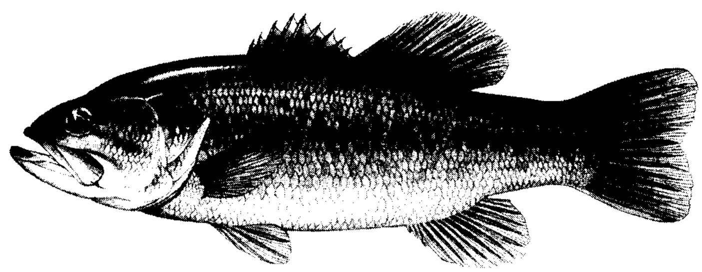
Removal of Unwanted and Overpopulated Species of Fish

Fish populations in poorly managed ponds usually become out of balance and may become contaminated with unwanted fish species. Texas ponds often become crowded with small or stunted bass or bluegill populations

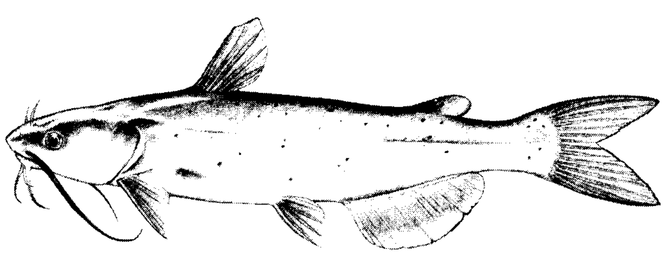
Fish species most commonly stocked in Texas ponds.



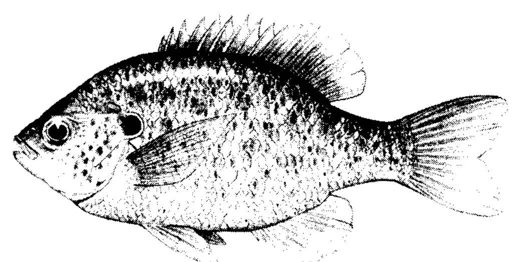
Bluegill



Largemouth Bass



Catfish



Redear Sunfish

or become populated with green sunfish, bullhead catfish, shiners or other unwanted species. The best management option in these situations may be to destroy all fish in the pond and start over. Removing or killing the fish population usually is much easier and less expensive if the pond can be drained dry or partially drained and the fish concentrated. Fish will survive in very small pools or puddles away from the main body of water. To get a complete kill you must treat all puddles, even those in the watershed, no matter how small!

Rotenone is a registered aquatic chemical that is used to kill fish. In Texas, rotenone for pond renovation can be purchased from most farm supply or feed-and-seed stores. You must have a private applicator license to purchase and use this chemical.

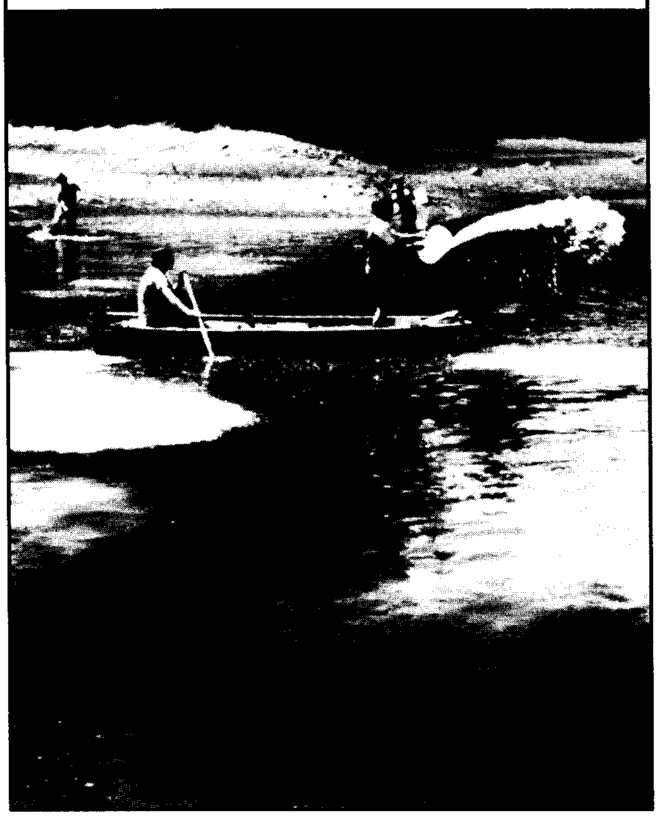
Rotenone comes in liquid or powder formulations, at a concentration of 5 percent active ingredient. Rotenone should be applied at a rate of 10 pounds per acre-foot. The volume of water in the pond (in acre-feet), or that remaining after draw-down, must be estimated so this concentration of rotenone can be calculated. One gallon of the liquid rotenone formulation (5 percent) is sufficient to treat approximately 1 acre-foot. The acre-feet in a particular pond can be calculated by multiplying the surface area in acres times the average depth in feet. For example, a 2-acre pond with an average depth of 6 feet would have 12 acre-feet, and would require 12 gallons of the liquid 5 percent formulation to treat.

Powdered rotenone should be mixed to a "soupy" consistency with water (about 2 gallons per pound of powder). Liquid rotenone also should be diluted with water at a rate of about 10 gallons of water to 1 gallon of rotenone. Apply rotenone evenly over the pond using buckets, sprayers or pumps. If the pond is more than 4 feet deep, use a hose to pump rotenone into deep sections of the pond. Rotenone applied properly and at recommended rates will not harm most livestock, even if they drink the water. Pigs, however, might be affected by the rotenone formulation, and ducks and geese may suffer if they gorge themselves on dead or dying fish. Caution: Make sure no water containing rotenone runs off your property to kill fish elsewhere!

Rotenone is usually applied in the summer or fall when water temperature is above 70 degrees F. Contact a fisheries biologist or county Extension agent for additional information on purchasing and applying rotenone.

Rotenone will dissipate within 3 to 10 days, depending on weather conditions. Generally it is safe to restock 2 to 3 weeks after applying rotenone. To check for the presence of rotenone, place a few small bluegill in a minnow bucket and float it in the pond. If the fish are still alive after 24 hours it is safe to restock.

Application of rotenone to kill unwanted fish populations. Pond was partially drained to concentrate fish and reduce risk of run-off.



Fertilization and Liming

Fertilization provides planktonic algae with nutrients for growth, much the same as fertilizing pasture increases grass yields. Proper fertilization increases available food throughout the food chain, thus increasing the amount of fish the pond supports.

Fertilization, however, will not stimulate a good algae bloom if the total alkalinity of the water is below 20 ppm. In East Texas, check the alkalinity of the pond first. If alkalinity is below 20 ppm, add agricultural limestone to neutralize acidity in the soils. Do not use quick or slaked lime; these will cause a rapid pH change that may kill fish. The amount of lime necessary depends on the characteristics of mud in the pond bottom. A mud sample should be analyzed to determine the amount of lime to add.

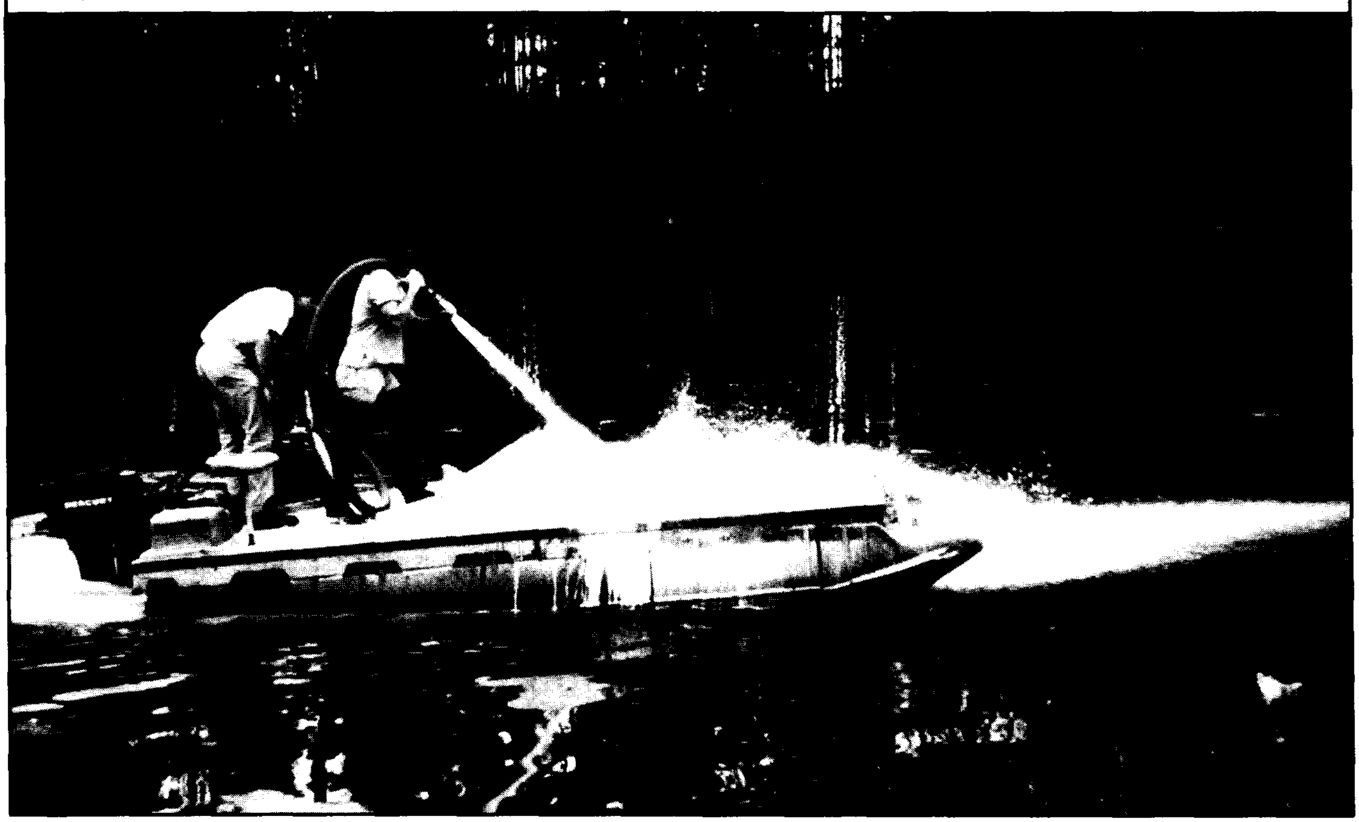
Take mud samples from many places in the pond. Combine these samples and spread them out to dry. After samples are dry, mix them together thoroughly and take one sample for analysis. Send this sample to the Texas A&M University Soil Testing Lab in a soil-test box (available from your county Extension office). Mark the sample "fish pond" so that the proper tests can be run. The analysis will recommend the proper liming rate.

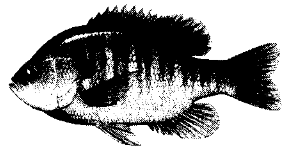
Lime must be applied evenly over the entire pond so that it can react with the bottom mud. If the pond is thoroughly dry, a spreader truck could distribute the lime. If the pond is full, however, the lime will have to be shoveled or washed into the pond from a boat. Several pond management consultants in Texas will lime ponds at a modest cost. Ask your county Extension office for a list of Texas Fisheries Consultants.

Lime slowly dissolves into the pond water and is washed out with overflow water. This means that ponds usually need to be relimed every 2 to 4 years. Many pond managers find it practical to increase the liming rate by one and a half or two times the amount recommended. This increases the length of time between lime applications. Some managers reapply half the recommended lime every 2 years to maintain alkalinity. Adding more than the recommended lime (agricultural lime only) will not harm the pond. A typical liming rate in East Texas is 2 tons per surface acre of pond. Remember, if a pond needs lime it will not respond well to fertilizer.

Fertilizing ponds will increase fish production two- to threefold. Infertile ponds will seldom produce more than 50 to 100 pounds of fish per acre. Well-managed, fertile ponds can maintain 300 to 400 pounds of fish per acre. If, however, the pond is naturally fertile and is not going to receive much fishing pressure, it may not require fertilizer. If the pond receives only minor fishing (or harvest) pressure, do not fertilize or fertilize at only half the recommended rate.

Lime application using a pontoon barge and water pump to evenly distribute the lime.





Once fertilization is started it should be continued. If fertilization is stopped the fish will be stunted because of the reduced food supply. This makes them more susceptible to disease.

Not all fertilizers work well in ponds. Phosphorus is the nutrient most needed in ponds. Given time, the phosphorus will be absorbed and trapped in the mud of the pond through chemical processes. Once trapped, it is not available to planktonic algae but can promote the growth of weeds and filamentous algae. Nitrogen is seldom needed in older ponds. Occasionally, new ponds need nitrogen, but once a pond is established nitrogen usually is abundant.

Fertilizers are labeled with N-P-K ratios or percents of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O). The equivalent of 8 pounds of granular—4 pounds of liquid—phosphorous per acre per application is commonly recommended. Liquid fertilizers can be easier to apply and may produce blooms quicker than granular fertilizers. Table 1 lists recommended rates for commonly available fertilizers.

Table 1. Recommended Fertilization Rates for Ponds.

Fertilizer formulation	Amount/acre/application
Granular	
20-20-5	40 lbs.
16-20-5	40 lbs.
18-46-0	18 lbs.
0-46-0	18 lbs.
Liquid	
13-38-0	1 gal.
10-34-0	1 gal.

A simple method of knowing when to fertilize is based on water clarity. The depth that light can penetrate into the pond is a measure of the algal density or bloom. Light penetration can be measured using a Secchi disk. A Secchi disk can be made from an 8-inch diameter disk of plywood, metal or plastic. Mark the disk into quarters and paint the two opposite quarters white and black, respectively. Attach the disk to a yardstick or to a pole marked at 12, 18 and 24 inches from the disk.

The optimum algae bloom is one that allows light to penetrate to a depth of 18 to 24 inches. Submerge the Secchi disk into the pond until it just disappears and note that depth. Follow Table 2 as a guide to fertilization.

Table 2. Recommendations for Fertilization and Management Based on Secchi Disk Readings.

Secchi Disk Reading	Recommended Management
Greater than 24 inches	fertilize
18 to 24 inches	good bloom - do nothing
12 to 18 inches	dense bloom - watch closely
12 inches or less	bloom too dense - determine source and be prepared to aerate at night
6 inches or less	oxygen depletion imminent

If the Secchi disk disappears between 18 and 24 inches there is no need to fertilize. It is time to fertilize again if the disk visibility is increasing rapidly toward 24 inches or if the disk is visible past 24 inches. If the disk disappears between 12 and 18 inches, the bloom is too dense; do not fertilize and watch the pond closely. If the disk disappears in less than 12 inches, the bloom is very dense and a severe oxygen depletion could occur. Remember, do not consider low Secchi readings that are the result of muddiness rather than algae.

A Secchi disk reading of 12 inches or less means the pond is too rich in nutrients. At that point you need to determine where excess nutrients are coming from. Have you over-fertilized? Are livestock manures or crop fertilizers entering the pond? If you are feeding the fish, are you overfeeding? Try to discover the source of the problem. Dense blooms can consume most of the pond's oxygen at night. Be prepared to aerate at night if the visibility is low and there are consecutive days of cloudy weather.

Granular fertilizers should not be broadcast into the pond. Granules will sink to the bottom and the phosphate will be absorbed directly into the mud and lost. Granules should be placed on a platform or in a permeable sack that is submerged about 12 inches underwater. Usually one platform is needed for every 10 surface acres of pond. Place the platform in an area of the pond that has wave action. Granules placed on the platform dissolve slowly, spread throughout the pond by water currents and stimulate a bloom.

Liquid fertilizers are dense and must be diluted with water before applying them or they will sink to the bottom and be absorbed into the mud. Dilute liquid fertilizers about 10 to 1 (water to fertilizer) and spray, splash or mix them into the pond. Apply fertilizer mixture as evenly as possible over the pond surface.

A Secchi disk can be used to determine when to fertilize.

Fertilization should begin in early spring. This first fertilizer application does not always stimulate a bloom. Continue to fertilize at 2- to 3-week intervals until the pond blooms green. Once a bloom is established, fertilize as necessary to maintain it. Use the Secchi disk guide in Table 3 to help make fertilization decisions. Continue fertilizing until late October.

One important word of caution: Do not fertilize ponds that are infested with aquatic weeds. The fertilizer will only stimulate growth of the weeds. Control weeds before fertilizing. Establishing a good fertilization program before weeds appear is one of the best methods of weed prevention.

Ponds that are flushed by large volumes of water will lose fertilizer more rapidly and may not sustain a bloom. In this case fertilization is usually ineffective and should be discontinued unless the excess water can be diverted (see Pond Construction). Many ponds will flush repeatedly in winter and early spring but respond well to fertilization in late spring, summer and fall.

Muddy ponds (12 inches or less visibility) usually will not respond to fertilization. Several methods have been used to clear muddy ponds; however, in most cases, the addition of lime to reduce acidity will settle a muddy pond.

Harvesting and Record Keeping

Improper harvest of largemouth bass ruins future fishing in more Texas ponds than any other cause. Pond owners and other anglers frequently overharvest the bass population in the first season of fishing. This allows bluegills to overpopulate in the pond. In some established bass populations, bass harvest is too low to remove a surplus of bass less than 12 inches long.

A pond owner can reduce the likelihood of bass overharvest by making his pond off limits to everyone. This practice is, however, not encouraged because underfishing can lead to almost as many problems as overfishing. Although the pond owner controls access to his pond, he should not deny entrance to a responsible sportsman asking permission to fish if he follows a few simple regulations regarding catch and release of certain sizes of fish. The pond owner should encourage all anglers to record their catches by species and size. This recordkeeping system provides an estimate of the size composition and relative abundance of game species over time.

Largemouth bass growth rates are influenced by a number of factors including genetics, water quality, habitat and forage availability. Statewide average growth rates for bass have been calculated: Age I - 8 inches; Age II - 12 inches; Age III - 15 inches; Age IV - 17 inches; and Age V - 18 inches. The most sensible way to prevent bass overharvest is to establish a 15-inch minimum length limit for a period of 3 years after stocking. If those who fish the pond abide by the restriction and release all bass less than 15 inches, the pond should begin producing good fish of all species. The bass that were originally stocked will have to support the majority of the catch for 3 years, so they have to be used wisely.

After 3 years a decision must be made. The decision will depend upon what kind of fishing is desired. Bass will have reproduced two or three times during this 3-year period and there may be a surplus of young bass. If unharvested, poor growth rates occur because of excessive competition. The result will be a bass population comprised primarily of individuals less than 12 inches long. All these small bass will effectively control bluegill numbers and the pond will have plenty of 7- to 8-inch bluegills.

If the pond owner is interested in catching bass more than 12 inches long, 8- to 12-inch bass must be harvested. About 25 8- to 12-inch bass (weighing 10 to 15 pounds) should be harvested per acre each year after the third year from stocking. The removal of these small bass reduces competition and allows some fish to attain lengths of 12 inches.

To keep bluegills in good condition, incorporate a "slot limit" where 12- to 15-inch bass are released from the third year on. Releasing bass of this size will also ensure that some bass will grow to more than 15 inches.

Plump bass (top) is in good condition, while skinny bass (bottom) is in poor condition and suggests "bass-crowded" pond.

If bass have not been harvested properly, the fish community may have to be adjusted. It is likely that bass overharvest has occurred if primarily 3- to 5-inch bluegills and few or no bass are caught. This problem can be rectified by stocking 40 8- to 12-inch bass per acre. Bass less than 15 inches long should be released until small bass become abundant. Then, bass less than 12 inches and more than 15 inches long can be harvested.

If only small bass and few bluegills are caught, harvest of bass has not been adequate. In this case, 30 3- to 5-inch bluegills should be stocked per acre. Approximately 25 8- to 12-inch bass should be harvested per acre each year thereafter. Again, 12- to 15-inch bass should be released. Bass larger than 15 inches should be released if "trophy" bass are the goal.

When a decision is made to stock a pond with limited numbers of larger bass and bluegills rather than fingerling fish, the few bass must be returned to the pond and carefully protected. One cannot afford to lose the few original fish.

Begin catfish harvest whenever the fish reach an edible size. Catchable size catfish should be checked for body condition. If it seems that many catfish caught are "skinny" it could be an indication of poor body condition caused by overcrowding (corrected by increased harvest) and/or inadequate food supply (corrected by increased feeding frequency).

Catch records are important for determining when supplemental stocking of catfish is needed. In catfish-only ponds, at least one-half of the original fish should be caught before restocking. Total weight of catfish in these ponds should not exceed 1,000 pounds per surface acre during the warm months to decrease the risk of fish losses from oxygen depletions. In ponds where catfish were stocked in combination with largemouth bass and forage species, occasional restocking may be necessary to maintain catfish populations over time. In these ponds, restock catfish at least 8 inches in length at the rate of 50 to 100 per surface acre at 2- to 4-year intervals. However, the total weight of catfish in "combination" ponds should not exceed 250 pounds per surface acre in order to decrease potential competition for food between species.

Evaluation of Pond Balance

Managers should assess fish populations in ponds every 1 to 2 years. More detailed information is given in "Assessment and Corrective Management for Fish Populations in Small Impoundments," Special Publication No. 2 of the Texas Chapter of the American Fisheries Society. Private fisheries consultants also can evaluate fish populations.

Pond balance can be checked by using a 15-foot minnow seine (1/4-inch mesh). The best time to check is early June. Seine several (at least three) shallow areas of the pond that are clear of brush and weeds. Allow the seine to arch or cup slightly as it is pulled, so that fish cannot easily swim around it. Samples from seining provide information on reproductive success and the presence of unwanted species.

Sampling with a 30-foot or larger (1/2- to 1-inch mesh) seine will provide further data for evaluating pond balance. Seine one or two 50-foot areas in the pond. Record the number of bluegill captured in groups: less than 3 inches; 3 to 5 inches; and longer than 5 inches. Also look at bass condition (that is, plumpness) and for unwanted species.

Refer to Table 3 to analyze pond balance from seine and catch data.

If fishing is adequate and seine data show both young bass and recently hatched bluegill fry, the pond is probably in balance. If no young bass and bluegill fry are found but many 3- to 5-inch bluegill are caught, your pond is probably out of balance. If you find undesirable species, it is time to poison and restock.

A balanced pond means that bream are available and abundant in sizes that allow for bass predation. As a bass grows it preys on larger bream.

Seining a pond in early June to check pond balance.

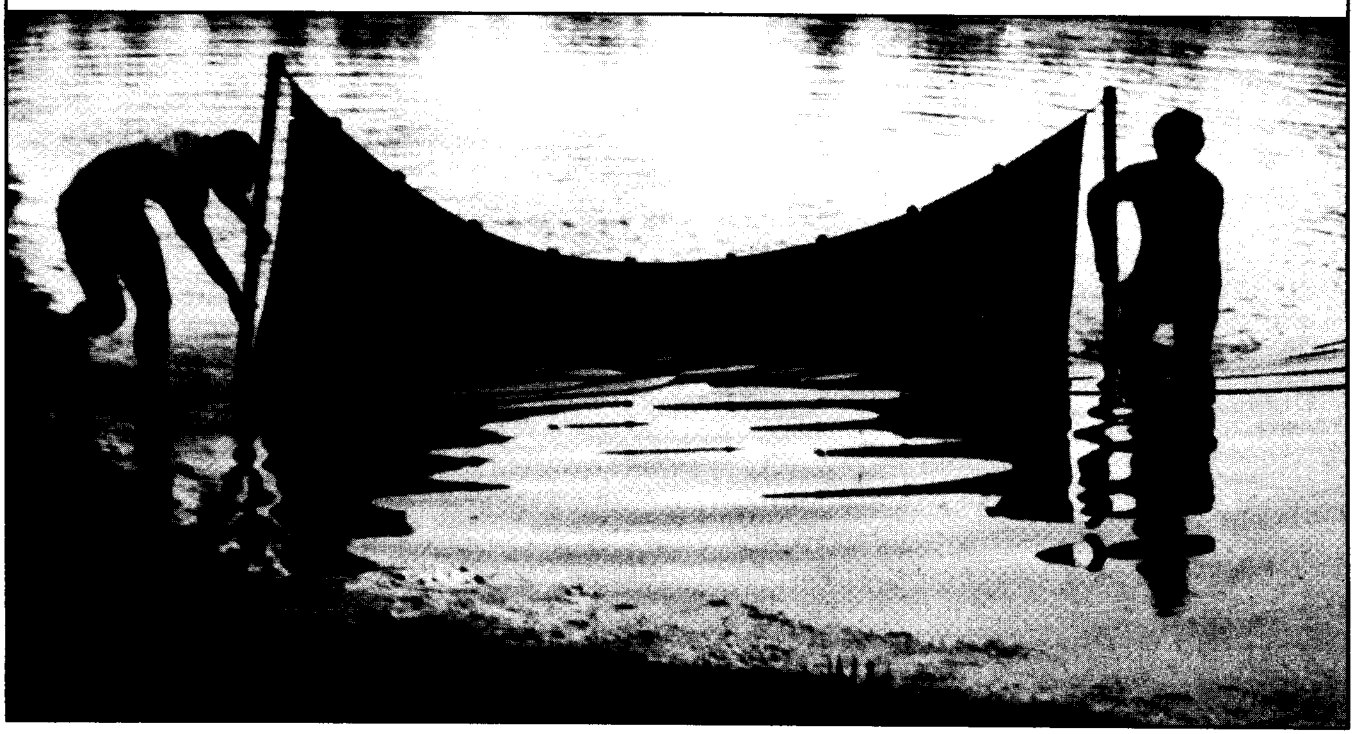


Table 3. Evaluation of Pond Balance Using 15-foot Seine and Catch Data.

Type of Fish Caught	Conclusion	Recommendation
Seine Data– small and intermediate bluegill and young of the year (YOY) largemouth bass Angler Catch Data– bass and bluegill of various sizes	fish populations in balance	no additional management necessary
Seine Data– many intermediate bluegill and few or no young of the year bass Angler Catch Data– few harvestable size bluegill; large bass	bluegill-crowded	remove intermediate bluegill by shore line rotenone in fall or stock 20-30 adult (≥12") bass per acre
Seine Data– few intermediate bluegill; many recently hatched bluegill Angler Catch Data– bass, numerous but small and thin; bluegill, few but large and robust	bass-crowded	remove 50-75 (35 lbs.) bass per acre stock 200, 3-5" bluegill per acre
Seine Data– unwanted species, no recent bluegill hatch, few intermediate bluegill Angler Catch Data– few harvestable size bluegill and unwanted species (crappie, bullhead, green sunfish, shiners, etc.)	fish populations dominated by unwanted species	rotenone and start over

Weed Control

Aquatic weeds are a common problem in farm ponds, although some aquatic vegetation might be good for the pond. Rooted aquatic vegetation does provide habitat for small aquatic animals, which adds to the food chain. Vegetation also provides small fish with places to hide from larger predators. The problem with weeds is uncontrolled growth. If too many weeds become established in the pond, too many small fish survive (overpopulate) and predators become thin because they are not able to prey on the forage species. Large growths of weeds also remove nutrients, which reduces algae production (food).

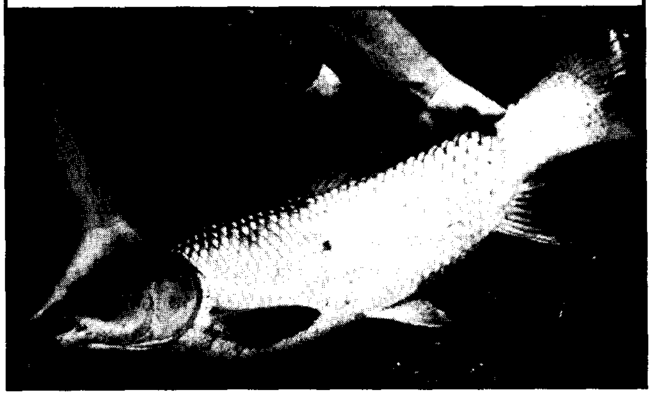
Aquatic weeds can be controlled by manual, chemical and biological means. Manual control of species such as cattails is practical when they first start to colonize a pond. Woody vegetation along the dam also can be controlled manually.

Chemical control with herbicides is possible but few herbicides are approved for aquatic use and the type of aquatic vegetation must be accurately identified before it is treated. Herbicides can kill planktonic algae, which leads to oxygen depletion. Oxygen depletion after herbicide treatment is particularly common in hot weather, if the pond is heavily infested with weeds, or in both conditions. Check with a fisheries biologist or your county Extension agent for plant identification information and current herbicide recommendations. When using chemical pesticides, protect yourself and others by strictly following all label directions.

The simplest and most economical long-term aquatic weed control method for aquatic weeds such as duckweed, hydrilla, pondweed and milfoil is to stock sterile triploid grass carp. The grass carp, or white amur, is an Asian carp brought to this county, for aquatic weed control. Grass carp consume vegetation almost exclusively after they reach 10 inches in length. They will not reproduce in the pond, will not muddy the pond like common carp, will not disturb the nests of other fish, and they consume 30 to 40 percent of their body weight in weeds every day during warm weather.

The use of grass carp is regulated by the Texas Parks and Wildlife Department. Contact the Department or your county Extension office for information on required permits, stocking rates and lists of available sources.

Grass carp grow rapidly and will control most underwater weeds if stocked at recommended rates.



Turn-Overs

Many of the basic problems of farm pond management have already been discussed. These include how to maintain a good food supply for the fish, how to harvest to maintain a balanced population, how to check balance, how to control weeds and how to avoid fish kills from algae bloom die-offs. These are not simple problems. Ponds are complex systems that take understanding and commitment to manage properly.

One common problem in Texas is pond "turn-over." Turn-overs occur when ponds are stratified; that is, surface water is warmer than the water below and the two layers no longer mix. This causes the cooler water near the bottom to stagnate and become depleted in oxygen. Fish avoid this layer of water. A turn-over occurs when the warm upper layer suddenly cools and mixes with the stagnant layer. The two layers mixed together may not have enough oxygen to support fish and they die. This usually occurs after a cold, hard rain. If a turn-over occurs, quick aeration may save the fish. Similar fish kills also can be caused by oxygen depletions from a bloom die-off or rotting vegetation from herbicide treatment.

Enhancement Strategies

Many techniques can be used to enhance fishing in ponds. Some of these include stocking fathead minnows for forage, constructing fish shelters, providing supplemental feed for fish, manipulating water level, aerating and destratifying.

Fathead minnows stocked at about 1,000 per acre the first year of a new or renovated pond will improve bass survival and growth. Fatheads should be stocked in February or March before the bass are stocked in June. Fatheads will spawn and produce abundant forage for the young bass. Bass will eliminate the fatheads within a few months and then turn to bluegill for forage.

Fish shelters or "attractors" can be made from many different materials (Figure 2). The purpose of a fish shelter is to provide a place for some small fish to escape predation and attract fish for anglers. These structures should be at a depth of 2 to 6 feet. Discarded Christmas trees and cedar trees make excellent shelters if anchored to the bottom. Stake beds (stakes driven into the bottom), rock piles and tire reefs are also good shelters. Usually only one reef is placed for every 1 to 3 acres, and no more than three per acre.

Supplemental feeding of commercial fish feeds increases bluegill and catfish growth. Bass do not readily consume artificial feeds but benefit from the increase in bluegill reproduction. Feeding can double the average size of harvestable fish and total pond production (up to about 600 pounds per acre). Fish can be fed throughout the warm months of the year, but best results are obtained by feeding from March through May and October through November when most bluegill growth occurs. Feed three or four times per day if possible. Feed in the same area and at about the same time of day. Feeding can be done by hand or with demand or automatic feeders. Floating feeding rings to contain the feed can be made from PVC tubing anchored in place. Provide one feeding station for every 3 acres of pond.

The protein level of the feed is not very important. Studies have shown that low protein feed (25 percent) will produce excellent growth. Therefore, it is not necessary to purchase high protein feed.

It is very important not to overfeed. A good rule of thumb is to feed all the fish will eat in 10 to 15 minutes, but not more than 10 pounds per acre per day. Winter feeding is not necessary but may increase bluegill growth. Feeding is expensive and can be justified only when there is an obvious need to increase production above that which can be supplied by fertilization and controlled harvest. Feeding stimulates plankton blooms in the same way as fertilization; thus, fertilization is usually unnecessary if feeding is done regularly. If feeding is not done on a regular basis it may be necessary to fertilize. Use the Secchi disk to determine if fertilization is needed (see Fertilization).

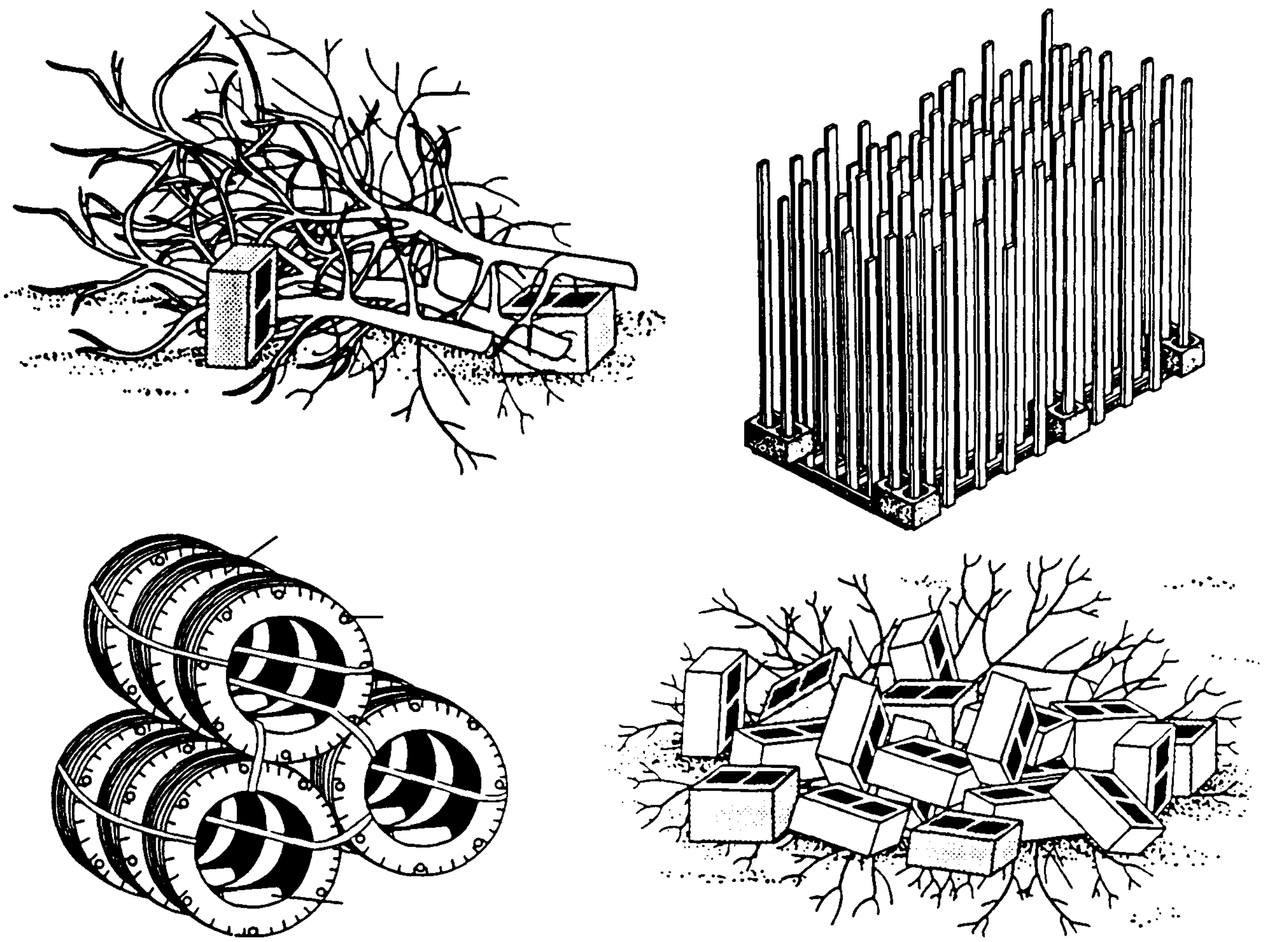
Ponds with drains have distinctive management advantages. Water level can be drawn down several feet (2 to 3) in late fall through mid-winter. This helps control aquatic weeds by exposing them to drying and freezing. Draw-downs also concentrate the fish, making forage fish more available to the bass. This increases bass growth and reduces bluegill overpopulation. The pond should be allowed to refill in February and March.

Ponds that have a history of fish kills will benefit from aeration or destratification (if deeper than 8 feet), or both. Many types of electric aerators are available. Supplemental aeration requires approximately 1/2 to 1 horsepower of aeration per surface acre of pond. If a turn-over or bloom die-off occurs additional aeration may be necessary.

Destratification, or the mixing of the pond to stop thermal layering, can be done using blowers, underwater fans and propeller aspirator type aerators. Each of these devices has advantages and disadvantages. Destratification will eliminate the chance of a fish kill caused by a turn-over and increase the area of the pond inhabited by the fish during the summer months. Destratification does alter algae blooms and may aggravate low oxygen problems during periods of overcast weather. For additional information on aeration and destratification devices, contact your county Extension agent or fisheries specialist.

Fish also can be encouraged to spawn where you want them to by providing them with a good spawning substrate. Place sand and gravel beds in several locations around the shoreline in 2 to 5 feet of water. The sand and gravel should be 4 to 6 inches deep and can be contained in a frame or box if the bottom is particularly silty. These beds allow the pond owner to concentrate seining efforts in areas where spawning should have occurred.

Figure 2. Reefs used as fish attractors.



Wildlife Enhancement

Wildlife, both game and nongame, require food, water and shelter to survive. If managed properly, ponds can provide fishing while at the same time providing food and shelter for a variety of wildlife species. Figure 3 depicts how the upper reaches of a pond can be managed for wildlife, while the lower areas adjacent to the dam have the characteristics of a typical fish pond. No more than half of the pond area should have water less than 2 feet deep. Ideally, the pond should be constructed so that the shallow areas can be dried by draining during May through October. Draining exposes an area of mudflats. In the mudflats natural vegetation may grow or specific plants can be planted. These mudflats are then flooded in the fall and provide habitat and a food source for ducks and other waterfowl. Draining and flooding can be accomplished by fitting the standpipe with two valves, one to drain the pond completely and the other positioned to drain only the upper reaches of the pond. Nesting boxes placed in the pond can provide artificial nesting cavities for wood ducks.

Ponds are watering sites for a variety of wildlife species. Cleared and sodded shorelines (15- to 20-feet wide) provide an unobstructed view of the pond and attract mourning doves and other bird species. Or, the shoreline can be planted with native trees and shrubs that provide seeds and fruits for wildlife to eat.

Wading birds, aquatic reptiles and amphibians are a natural part of any pond. These animals can provide many hours of enjoyment to those who have the opportunity to watch them.

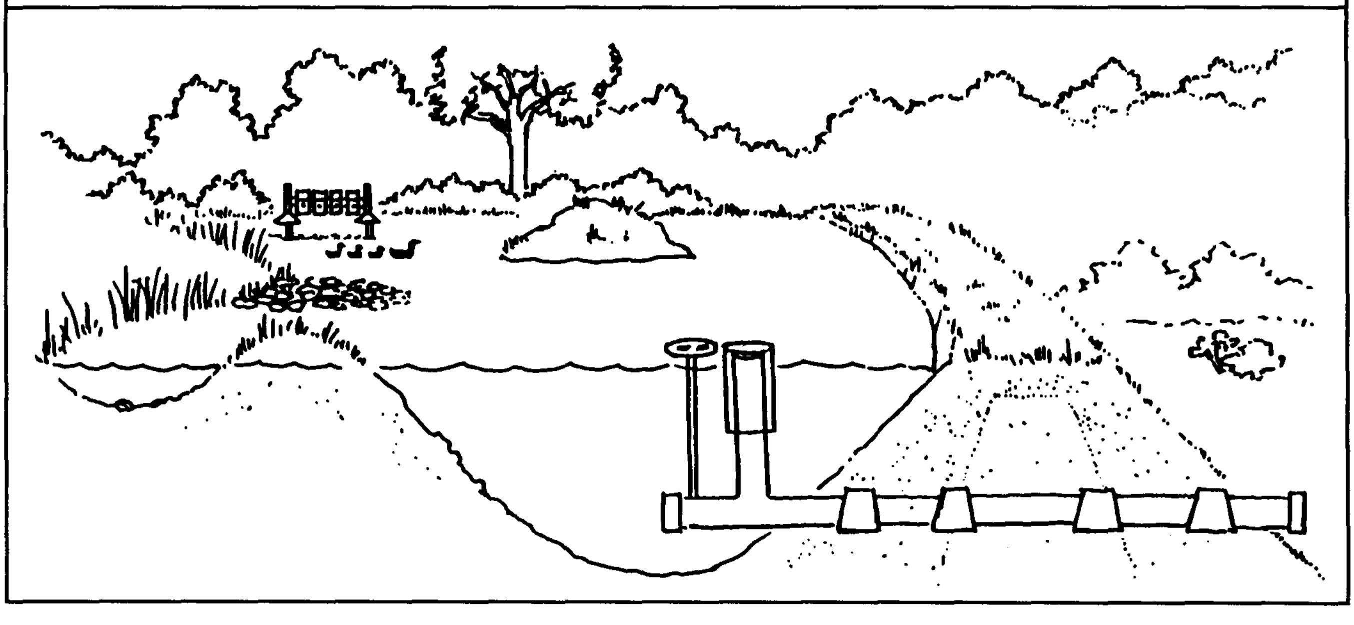
Whether it is waterfowl to be hunted or nongame species to be watched, wildlife can enhance the recreational benefits of ponds. Contact your county Extension office for more information on maximizing wildlife around a pond.

Summary

Small farm ponds are not mother nature's creations; they are the work of human beings. They must be managed to be productive and provide good fishing. Think of a pond as you would a garden or orchard. It must be properly laid out, fertilized, planted (stocked), weeded, pruned (in this case selectively harvested) and protected from climate-related catastrophe (for example, turn-overs) in order to be bountiful. All of this takes time and effort, but the rewards are outdoor recreation and good food.

All fishing should be recorded (see Table 4). Write in the number of fish caught under the various species fished for, or zero if none were caught. One person should initial each entry in case further information is needed.

Figure 3. Shallow areas attract wildlife (top), while deeper pond areas are typical fishing pond.



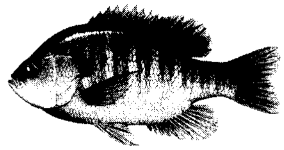


Table 4. Catch Record.

All fishing should be recorded; provide number of fish caught; if no fish caught place zero under species fished for; record time spent in hours–one person initial in case further information needed.

Date	Number Fishing	Initials	Bass						Bluegill				Catfish			Other
			12"		12-15"		15"		6"		6"+		Length			Number Species
			k	r	k	r	k	r	k	r	k	r		k	r	

k = kept or taken from the pond

r = released back into the pond

Acknowledgements

A special thanks is extended to artist/naturalist Rick Hill, Kentucky Department of Fish and Wildlife Resources, for the use of his illustrations.

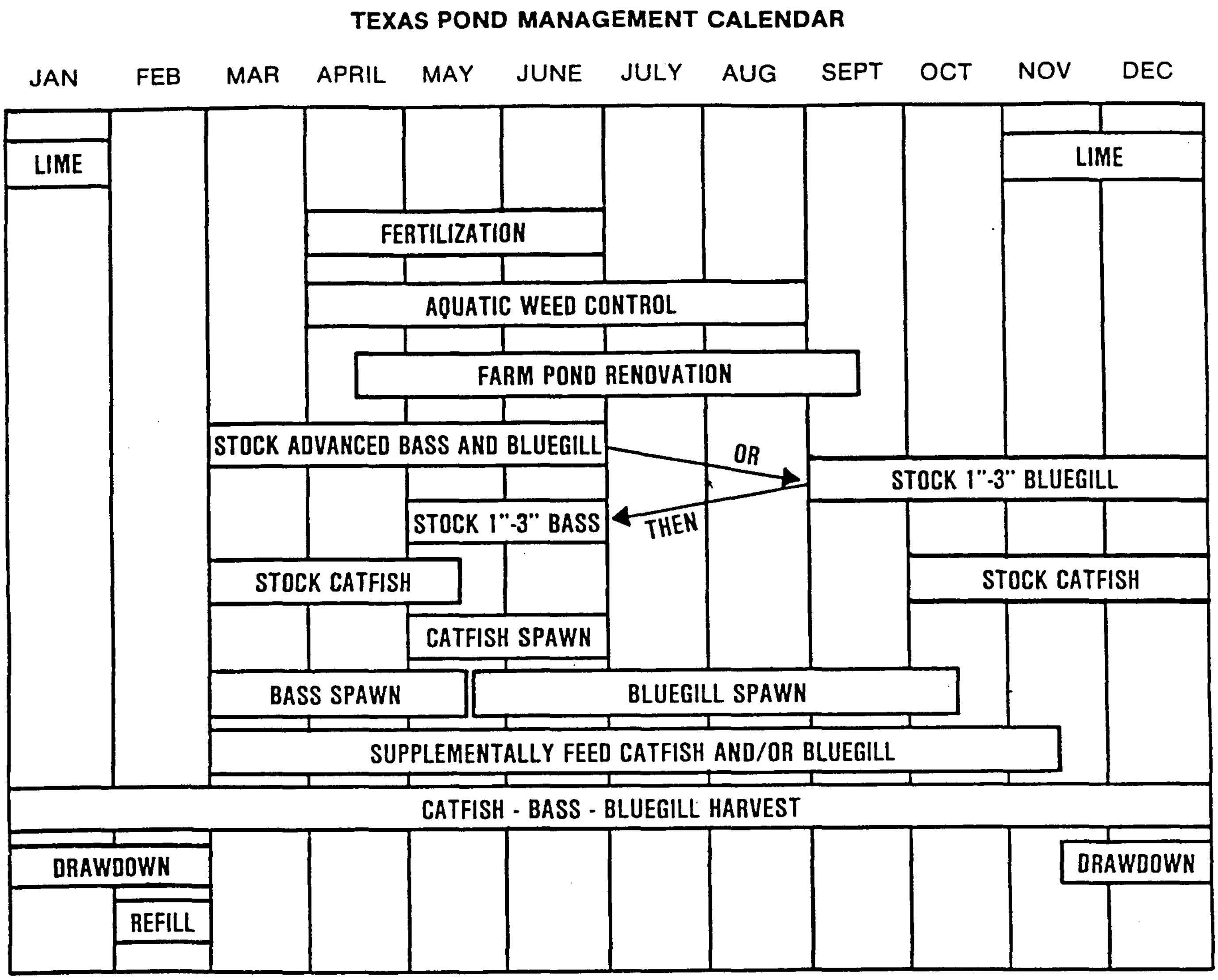
Thanks also to Mike Masser, Extension Fisheries Specialist, and Carol Whatley, Extension Communications Specialist, Alabama Cooperative Extension Service, for providing the bulletin "Management of Recreational Fish Ponds in Alabama" on which this publication is based.

Issued in furtherance of Cooperative Extension Work in Agriculture and Home Economics, Acts of Congress of May 8, 1914, as amended, and June 30, 1914, in cooperation with the United States Department of Agriculture. Zerle L. Carpenter, Director, Texas Agricultural Extension Service, The Texas A&M University System.

20M—9-93, Revision FISH 5

TEXAS FARM POND MANAGEMENT CALENDAR

Billy J. Higginbotham*



- **LIME** - Agricultural limestone applications are necessary in ponds with a pH below 6.5 and total alkalinity below 20 ppm. Waters in this category may limit fish growth and reproduction. East Texas ponds in particular should be tested before stocking.
Best months: November-January.

- **FERTILIZATION** - Inorganic fertilizer can be utilized to double fish production by increasing the food supply. Use granular 20-20-5 at 100 pounds/surface acre followed by one or two reduced rate applications of 35 pounds/surface acre as needed to maintain the bloom. Liquid fertilizer such as 16-34-0 is also utilized at one

*Wildlife and Fisheries Specialist, Cooperative Extension Program, Prairie View A&M University

Great Trinity Forest Management Plan

Wildlife Management

Texas Farm Pond Management Calendar

gallon/surface acre every two weeks in the spring. Never fertilize and lime a pond at the same time. Fertilization should be continued on an annual basis.
Best months: Start in early April, end in June.

• **AQUATIC WEED CONTROL** - Initiate chemical weed control when growth begins in the spring. Proper plant identification is essential to providing good control. Do not treat an entire pond with heavy weed infestations in the summer. Spot treat in hot weather to avoid an oxygen depletion.
Best months: Start in April or May - spot treat throughout summer as needed.

• **FARM POND RENOVATION** - Ponds that become out of balance due to a stunted fish population and/or undesirable species should be renovated utilizing rotenone. Liquid or powder 5 percent rotenone at 10 pounds powder or one gallon liquid/acre foot of water kills most problematic species. Treated water is safe for livestock. Restocking is possible three weeks after treatment.
Best months: April-September (when water temperature is above 70°F).

• **STOCKING** - Use these rates on new or renovated ponds only (no fish present). Muddy ponds and all ponds less than one surface acre should be stocked only with catfish and fathead minnows (at 500/surface acre as supplemental forage). Catfish stocking rates range from 100 to 1000 fingerlings per acre depending on the frequency of feeding. **Best months:** March-May or October-December. Ponds larger than one surface acre are suitable for management of bass-bluegill or bass-bluegill-catfish. Occasionally, supplemental forage species (threadfin shad, fathead minnows, golden shiners and/or redear sunfish are stocked in addition to the bluegill. Stock 20 six to eight inch bass and 30 three inch or larger bluegill per surface acre if available. **Best months:** March-June. If only one to three inch bass and bluegill are available, stock 500 bluegill/surface acre in the fall followed by 50 bass/surface acre the next spring. Catfish stocked with bass-bluegill should be at least as large as the bass fingerlings (stocking rate 100/surface acre). All stocking rates for bass-bluegill-catfish strategies can be doubled if a fertilization program is utilized.

• **SPAWNING** - Catfish stocked alone should not be encouraged to reproduce by adding spawning habitat. However, when stocked with bass and bluegill, the addition of tires, culverts, etc., into the lake is recommended to increase catfish reproduction. Bass initiate spawning in March with some females spawning two or three times before summer. Bluegill are essential as bass forage because of their ability to spawn throughout the summer (May-October), providing abundant forage for maintaining a bass population.

• **SUPPLEMENTAL FEEDING** - Supplemental feeding greatly increases the pounds of catfish that can be supported in ponds and lakes. Bluegill also benefit from a regular feeding program. Use a floating ration containing at least 28 percent crude protein. Feed at three percent body weight or all that will be eaten by the fish in 10-15 minutes. Feed may also be offered once a week during the winter on warm, sunny days only.
Best months: March-November.

• **HARVEST** - Hook and line harvest is encouraged whenever catfish reach edible size. Catfish produced for income should be removed and sold (if appropriate) by the end of the growing season (November-December). However, since most pondowners simply raise catfish for their own recreation, carry-over of fish from one year to the next is common. Mature fish (3-4 years) may spawn and the resulting offspring stunt or the carrying capacity of the pond (maximum of 1000/pounds/surface acre with daily feeding) will be exceeded if the fish are not routinely harvested. Return all bass less than 15 inches long during the first three years after stocking. From the fourth year on, remove bass caught less than 12 inches, return 12-15 inch bass, and keep or return those bass over 15 inches. Do not remove more than 20 pounds of bass per surface acre per year to prevent overharvest. No limit should be placed on the number of bluegill harvested.
Best months: All year.

• **CATCH RECORDS** - Anglers should maintain accurate records on the numbers and sizes of each species caught during each fishing trip. Harvest can then be monitored to determine when restocking and/or restrictions applicable to certain species become necessary.
Best months: All year.

• **DRAWDOWN** - Ponds larger than one surface acre containing bass and bluegill may benefit from annual drawdown of one to three feet. This technique concentrates forage (bluegill) and makes them more available to bass. Exposed shoreline areas can be planted with a combination of winter grasses following drawdown to provide nursery habitat for sportfish fingerlings the next spring.
Best months: Drawdown in late October, refill before bass spawning season (March).

Great Trinity Forest Management Plan

Wildlife Management

Barred Owl

(Strix varia)

Barred owl
(*Strix varia*)

The barred owl is a forest dweller that occurs in Canada, United States and Mexico. This is a large, nonmigratory bird that reaches 43-50 cm (16.9-19.7 in) long and 470-1,050 grams (1-2.3 lbs). Predators include larger hawks, great horned owl (*Bubo virginianus*) and raccoons (*Procyon lotor*). (Mazur and James 2000)

Food

Barred owls are seminocturnal to nocturnal predators who mainly hunt from perches. Mazur and James (2000) call this species a true generalist predator which mainly eats small mammals such as voles, rats, mice and shrews but can take prey up to the size of a rabbit. In fact, small mammals have been found to make up 65.9 to 100 % of the diet; however, it also forages on fish, amphibians, reptiles, invertebrates, and birds up to the size of a grouse. (Allen 1987, Mazur and James 2000, Holt and Bitter 2007)

Water

The water requirements of this species are unknown.

Habitat

This species is a resident of densely forested areas, especially older stands that are free of a dense understory. This is supported by a study conducted in Oklahoma which found that in a core area for a breeding pair consisted largely of closed canopy forest (more than 40% canopy cover) even though other areas such as fallow fields and open canopy forest was still in the core area (Winston and Lesile 2004). It will use younger forests if large diameter trees or snags are present and it will forage in other habitat types if perches are present. Studies have shown that the range of this species can be between 86.1 - 369 ha (212.8 - 911.8 ac) (Allen 1987).

Reproduction

This is a secondary cavity nester which also use nest boxes and old hawk nests. This species is usually seen nesting in deciduous forests, especially in riparian and lowland areas. Barred owls use cavities ≥7.6m (24.9 ft) above the ground in alive or dead decadent trees. Allen (1987) recommends that cavity trees with a dbh greater than 50.8 cm are suitable for nesting.

Management

One of the factors which may limit this bird is the presence of cavity trees. Allen (1987) recommends more than 2 trees per 0.4 ha (1 ac) that are greater than 51 cm (20 in) dbh and that the mean dbh of the overstory trees is greater than 51 cm (20 in). This can be achieved by using a long forest rotation and retaining vertical structures such as snags. If there is inadequate cavity trees or snags, then nest boxes may be used. Since this species prefer dense stands, the canopy closure of the overstory trees should be more than 60%. (Allen 1987)

Literature Cited

Allen, A.W. 1987. Habitat Suitability Index Models: Barred Owl. U.S. Fish and Wildlife Service, Biological Report 82(10.143). 17 pp.

Holt, D. W. and C. Bitter. 2007 barred owl winter diet and pellet dimensions in Western Montana Northwestern Naturalist 88:7–11

Mazur, K. M., and P. C. James. 2000. Barred Owl (*Strix varia*). *In* The Birds of North America, No. 508 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Winton, B.R. and D.M. Leslie, JR 2004. Density and Habitat Associations of Barred Owls at the Edge of their Range in Oklahoma. Southeastern Naturalist 3(3):475–482

-tcm

BIOLOGICAL REPORT 82(10.143)
SEPTEMBER 1987

HABITAT SUITABILITY INDEX MODELS: BARRED OWL

Fish and Wildlife Service

U.S. Department of the Interior

Biological Report 82(10.143)
September 1987

HABITAT SUITABILITY INDEX MODELS: BARRED OWL

by

Arthur W. Allen
National Ecology Center
U.S. Fish and Wildlife Service
2627 Redwing Road
Fort Collins, CO 80526-2899

National Ecology Center
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

This report should be cited as:

Allen, A.W. 1987. Habitat suitability index models: barred owl. U.S. Fish Wild. Serv. Biol. Rep. 82(10.143). 17 pp.

PREFACE

This document is part of the Habitat Suitability Index (HSI) model series [Biological Report 82(10)], which provides habitat information useful for impact assessment and habitat management. Several types of habitat information are provided. The Habitat Use Information section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. This information provides the foundation for the HSI model and may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model section documents the habitat model and includes information pertinent to its application. The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The HSI Model section includes information about the geographic range and seasonal application of the model, its current verification status, and a list of the model variables with recommended measurement techniques for each variable.

The model is a formalized synthesis of biological and habitat information published in the scientific literature and may include unpublished information reflecting the opinions of identified experts. Habitat information about wildlife species frequently is represented by scattered data sets collected during different seasons and years and from different sites throughout the range of a species. The model presents this broad data base in a formal, logical, and simplified manner. The assumptions necessary for organizing and synthesizing the species-habitat information into the model are discussed. The model should be regarded as a hypothesis of species-habitat relationships and not as a statement of proven cause and effect relationships. The model may have merit in planning wildlife habitat research studies about a species, as well as in providing an estimate of the relative suitability of habitat for that species. User feedback concerning model improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning are encouraged. Please send suggestions to:

Resource Evaluation and Modeling Section
National Ecology Center
U.S. Fish and Wildlife Service
2627 Redwing Road
Ft. Collins, CO 80526-2899

CONTENTS

FIGURES

ACKNOWLEDGMENTS

This HSI model was initiated in two modeling workshops hosted by the U.S. Fish and Wildlife Services' Gloucester Point, VA, and Lafayette, LA, Field Offices of the Division of Ecological Services. Participants in the Virginia workshop included: Karen Mayne and Gary Fraser, Division of Ecological Services, Gloucester Point, VA; Deborah Rudis, Susanne Nair, and Charlie Rewa, Division of Ecological Services, Annapolis, MD; Bob Hume and Doug Davis, U.S. Army Corps of Engineers, Norfolk, VA; John Badin, U.S. Army Corps of Engineers, Wilmington, NC; and Charlie Rhodes, U.S. Environmental Protection Agency, Philadelphia, PA. Participants in the Lafayette workshop included the following Division of Ecological Services biologists: Robert Strader, Lafayette, LA; Danny Dunn, Daphne, AL; Robert Willis, Cookeville, TN; and Robert Barkley, Steve Forsythe, and Charles McCabe, Vicksburg, MS. Brian Cade, Patrick Sousa, and the author, U.S. Fish and Wildlife Service, Fort Collins, CO, served as facilitators of the workshops.

Subsequent to the workshops, reviews of the draft model were provided by Robert Barkley, Steve Forsythe, Charles McCabe, Robert Strader, and Robert Willis. The time and contributions of these individuals are sincerely appreciated.

The revised draft was reviewed by Dr. Mark R. Fuller, U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, MD; Mr. Tom Hamer, U.S. Forest Service, Sedro Woolley, WA; and Dr. Jerome A. Jackson, Mississippi State University, Mississippi State. The additional information provided, as well as the time and willingness of these individuals to contribute to the improvement and completion of this model, is gratefully acknowledged.

The cover of this document was illustrated by Jennifer Shoemaker. Word processing was provided by Dora Ibarra. Kay Lindgren assisted with literature searches and information acquisition.

BARRED OWL (*Strix varia*)

HABITAT USE INFORMATION

General

The barred owl (*Strix varia*) is widely distributed throughout North America, ranging from the east coast to western Canadian Provinces (American Ornithologists' Union 1983). The species has recently expanded its range into extreme western Canada and the northwest United States (Fyfe 1976; Taylor and Forsman 1976; Boxall and Stepney 1982; Marks et al. 1984). In the midwestern and eastern portions of North America the species is associated primarily with mixed woodland, boreal forest, mixed transitional forest, and deciduous forest (Boxall and Stepney 1982). For successful inhabitation the species requires an expansive forested area that contains large mature and decadent trees that provide cavities suitable for security and reproduction.

Food

The diet of the barred owl is governed by availability of prey. The species is primarily nocturnal (Taylor and Forsman 1976), although diurnal foraging and activity is not uncommon (Caldwell 1972; Fuller 1979). Small mammals are the primary component of the barred owls' diet (Wilson 1938; Earhart and Johnson 1970; Holgersen 1974; Hanebrink et al. 1979). Meadow voles (*Microtus pennsylvanicus*), short-tailed shrews (*Blarina brevicauda*), and white-footed mice (*Peromyscus leucopus*) composed the bulk of the barred owls' prey in Ohio (Dexter 1978). Small mammals accounted for 65.9% of the prey items recorded in Maryland (Devereux and Mosher 1984). Rats, mice (Cricetidae), and shrews (Soricidae) composed 81.5% of the mammalian prey. Meadow and montane voles (*M. montanus*) composed 96.3% of the total winter food of barred owls in Montana (Marks et al. 1984).

Fish, amphibians, reptiles, birds, and invertebrates generally account for a smaller portion of the barred owls' diet (Earhart and Johnson 1970). Birds and arthropods accounted for 14.6% and 19.5%, respectively, of the total number of prey items consumed by barred owls in Maryland (Devereux and Mosher 1984). Investigations in Mississippi, however, suggest that invertebrates, primarily crayfish, exceed small mammals in importance in the barred owls' diet (J.A. Jackson, Department of Biological Sciences, Mississippi State University, Mississippi State; letter dated June 23, 1987).

Water

Information pertaining to dietary water requirements of barred owls was not located in the literature.

Much of the earlier literature pertaining to barred owl ecology (Carter 1925; Errington and McDonald 1937; Bent 1938; Applegate 1975; Soucy 1976) concluded or implied that barred owls prefer to establish nests in close association with water or within forested wetland cover types. More recent and exhaustive investigations tend to disprove the conclusion that the species prefers to nest in close proximity to water. Devereux and Mosher (1984) did not record differences in the distance to water from nest sites and random sample plots in Maryland. Furthermore, radiotelemetry investigations (Nicholls and Warner 1972; Fuller 1979) have shown that barred owls consistently used suitable upland forest cover types more frequently than forested wetlands and lowlands. Devereux and Mosher (1984) concluded that the relationship between barred owls and forested wetland cover types was a result of the vegetation associated with these cover types rather than an attraction for the water itself. Forested wetlands are often inaccessible or too wet for timber harvesting. As a result, these sites often contain remnant stands of mature and old-growth forest. The large size classes and decadent nature of these forests provide ideal cover and nest cavities, thereby attracting and supporting barred owl populations.

Fifty-five percent of barred owl observations in the Pacific Northwest have been reported near a wetland cover type (T. Hamer, U.S. Forest Service, Sedro Woolley, WA; unpubl.). The apparent relationship between barred owls and wetlands may stem from past forest management in the region (Hamer, pers. comm.). In the Pacific Northwest, low elevation forests historically have been those initially subjected to timber harvest and management. Low elevation areas in this region contain a greater abundance and distribution of wetlands than do tracts of higher elevation and steeper topography. Older seral vegetation stages now occur in these areas, resulting in mixed coniferous and deciduous stands that provide suitable barred owl habitat, frequently in relatively close proximity to wetlands.

Cover

The survival of the barred owl depends on the availability of suitable food and forested areas that provide adequate conditions for perching, courtship, and reproduction (Nicholls and Warner 1972; Elody and Sloan 1985). Barred owls appear to prefer older stands, but earlier stages of forest succession will be used if a suitable number of large diameter trees or snags is present (Hamer, pers. comm.). Although barred owls occasionally may be found in small woodlots, they are much more likely to inhabit extensive tracts of forest (Jackson, unpubl.). The barred owl is most frequently associated with densely forested woodlands and deciduous and mixed deciduous/coniferous forests (American Ornithologists' Union 1983); however, barred owls are not restricted to specific floristic associations in their foraging activities (Fuller 1979). Deciduous woodlands, specifically riparian and lowland areas, were the most frequently recorded forest types for barred owl nesting throughout North America (Apfelbaum and Seelbach 1983). Establishment of nests in pure coniferous cover types has not been recorded in the midwest and has been recorded only infrequently elsewhere in North America.

Definite preferences for specific cover types were exhibited by barred owls in Minnesota (Nicholls and Warner 1972). Cover types in order of preference were (1) oak (Quercus spp.) woodland, (2) mixed deciduous/coniferous woodland, (3) white cedar (Thuja occidentalis) swamps, (4) oak savanna, (5) alder (Alnus spp.) swamps, (6) marshes, and (7) old fields. Oak woodland and mixed deciduous/coniferous cover types contained trees that provided perch sites and cavities and cover for prey species. The first four cover types were normally free of dense understory vegetation, that might have facilitated foraging through increased visibility and reduced obstructions to flight. McGarigal and Fraser (1984) also found barred owls in forested cover types that were relatively free of understory vegetation and other obstructions that would impede the owls mobility and foraging success. Nest sites in Maryland were located significantly closer to forest openings than were random sites in cover types with well developed understory vegetation (Devereux and Mosher 1984). Nicholls and Warner (1972) attributed the barred owls' preference for upland woodlands to drier conditions on the forest floor, as compared to wetter lowland sites, and the likelihood that prey were easier to hear and locate under dry conditions. Lower use of white cedar swamps by barred owls was attributed to an absence of suitable nest sites, lower prey availability, and less than ideal hunting conditions (e.g., muffled noise due to wet substrate and dense understory). The relatively open oak savanna cover type received lower use by barred owls. Although prey were believed to be abundant in this cover type, the trees present were smaller in height and diameter than those within the oak and mixed woodlands, resulting in a lack of suitable cavities and decadent trees. The barred owls' low use of alder swamps was attributed to extremely dense tree canopy cover that could inhibit the owls' mobility and foraging success. Suitable cavities and nest trees were absent in this cover type. Marshes and open fields did not contain suitable trees for perch sites or cover. Although prey were abundant in the old field cover type, they were not accessible. No seasonal differences in preference for these cover types, nor major differences in the intensity of cover type use between sexes, were recorded.

Most observations of barred owls in Alberta have been reported in mixed woodland, boreal forest, and montane forest (Boxall and Stepney 1982). The relative absence of barred owl observations in Alberta's aspen (Populus spp.) parkland was attributed to the absence of large, mature trees and the consequent lack of suitable cavities. The majority of barred owl observations in British Columbia have occurred in the Columbia Forest Biotic Area in which western hemlock (Tsuga heterophylla) and western redcedar (Thuja plicata) are the major climax species (Grant 1966).

Establishment of mixed deciduous and coniferous stands subsequent to clearcutting in the Pacific Northwest has enhanced habitat conditions for barred owls (Hamer, pers. comm.). Release of understory and invasion by pioneer species [e.g., alder, vine maple (Acer circinatum), and bigleaf maple (A. macrophyllum)], combined with the breaking up of large tracts of purely coniferous forest, have provided suitable habitat and may be a key reason behind the barred owls' range expansion in the Pacific Northwest in recent decades. Analysis of four decades of barred owl detections (collected specimens, calls, and visual sightings) in the Pacific Northwest provide the following examples of where the species occurs in this region (Hamer, unpubl.).

Eighty-three percent of observations (n=140) were at sites <1,067 m in elevation (range: sea level to 1,981 m). Although barred owls were observed in a wide variety of stand types, the common characteristic was the presence of large, mature or old-growth trees required for cover and nesting. Sixty-two percent of observations occurred in coniferous associations, 17% in mixed coniferous/deciduous and 6% in deciduous cover types. The remaining observations (15%) were recorded in city/urban and roadside vegetation. Analysis of successional stage showed the following relationship to barred owl observations: old-growth, 53%; mature, 23%; medium-sized sawtimber, 10%; pole-sapling, 12%; and mixed old-growth/pole sapling, 1%. No observations were recorded in scrub/shrub or grass-forb cover types.

Reproduction

Barred owls often nest in interior portions of expansive, mature woodland (Dunstan and Sample 1972; Elody 1983). Primary barred owl reproductive habitat in the southeastern United States was described as forested wetlands and bottomland hardwoods in the Piedmont and Coastal Plain, and wooded stream courses and stands of spruce (Picea spp.), fir (Abies spp.), or hemlock (Tsuga spp.) in mountainous regions (Hamel et al. 1982). Stands composed of sapling to pole-sized trees were described as marginal reproductive habitat in southern mixed mesic hardwoods. Sawtimber-sized trees (≥51 cm dbh) were thought to be indicative of potentially optimum reproductive habitat, as few nests are established in stands of immature trees or in relatively small woodlots. All barred owl nests located in Maryland were situated in stands of old-growth timber (Devereux and Mosher 1982). Within these stands there were significantly more trees >50 cm dbh than in random sites, (45/ha compared to 5/ha in random sites). Old-growth stands in Virginia that were inhabited by barred owls appeared to have lower stem densities and more subcanopy flying space than did younger stands (McGarigal and Fraser 1984). Barred owl reproductive habitat in Washington was described as dense, >80 years-old, second-growth, mixed hardwood-conifer forest (Leder and Walters 1980).

Summarizing nest site data from across North America, Apfelbaum and Seelbach (1983) reported that elm (Ulmus spp.) and beech (Fagus spp.) were the most frequently used nest trees. Unidentified oaks, hickories (Carya spp.), yellow birch (Betula alleghaniensis), sycamore (Platanus occidentalis), and aspen also were used occasionally for nesting in midwestern North America.

The typical barred owl nest tree is tall, decadent, and has a suitable cavity or nest site ≥7.6 m above the ground (Dunstan and Sample 1972). Nests are most frequently established in cavities in large living or dead trees (Apfelbaum and Seelbach 1983). The majority of nest sites observed in Mississippi have been in cavities in living trees (Jackson, unpubl.). Living trees are believed to provide superior nest sites to those of snags due to the additional cover provided by foliage. Cavities in large trees composed 80.8% of the nest sites located in Michigan (Elody 1983). Nests also have been recorded in the tops of broken snags (LeDuc 1970; Devereux and Mosher 1982) and in unoccupied hawk nests (Eckert 1974; Apfelbaum and Seelbach 1983). Devereux and Mosher (1984) postulated that barred owls fledged from hawk nests may become inprinted on this type of nest and may subsequently nest in suitable abandoned nests regardless of cavity availability.

Recommended dbh for cavity trees suitable for barred owl nesting is ≥50.8 cm (Evans and Conner 1979; Hamel et al. 1982). The average height of nests in Michigan was 9.1 m (range: 1.5 to 30.4 m) (Apfelbaum and Seelbach 1983). Cavities used for nesting in Maryland averaged 3 m higher than randomly sampled cavities (Devereux and Mosher 1984). Cavities >9 m above the ground may be preferred. Carmichael and Guynn (1983) estimated that the minimum number of snags/ha required to support various population levels of barred owls were as follows: 100% of potential population = 0.1 snag/ha, 60% of potential population = 0.05 snag/ha, and 20% of potential population = 0.02 snag/ha.

Interspersion and Composition

Barred owls frequently traveled between separate woodlots within their home range in Minnesota (Nicholls and Warner 1972). Fuller (1979) reported that barred owls frequently occurred along field/forest edge and that the species will forage within several cover types if perch sites are available. Cover types that typically receive little use by barred owls (e.g., marshes, old fields) might be important in that they generally support high production of prey species and can serve as source areas for prey immigration into cover types more heavily used by barred owls.

The average home range for barred owls in Minnesota was 228.6 ha (range = 86.1 to 369.0 ha) (Nicholls and Warner 1972). Differences between home range sizes of barred owls appeared to be associated with breeding status and season or age (Fuller 1979). The average cumulative home range, based on minimum area, for breeding females in Fuller's Minnesota study was 507.8 ha. Average home range size for barred owls in Michigan's upper peninsula was 282 ha (Elody and Sloan 1985). The area used decreased to an average of 118 ha during the summer months.

Special Considerations

Barred owls will successfully use artifical structures for nesting (Johnson 1980). Johnson and Follen (1984) provided guidance for the construction of nest boxes suitable for barred owls. Devereux and Mosher (1984) concluded that intensive forest management, where stands are harvested at <80 years, may cause a decline in the number of nesting barred owls due to the loss of suitable cover (i.e., old-growth) and nest sites. Retention of a few mature trees might maintain the owls' cover requirements. The preservation of older maple and yellow birch may prevent declines in barred owl populations in intensively managed forest stands in Michigan (Apfelbaum and Seelbach 1983).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This HSI model has been developed for application throughout the barred owls' range (Figure 1).

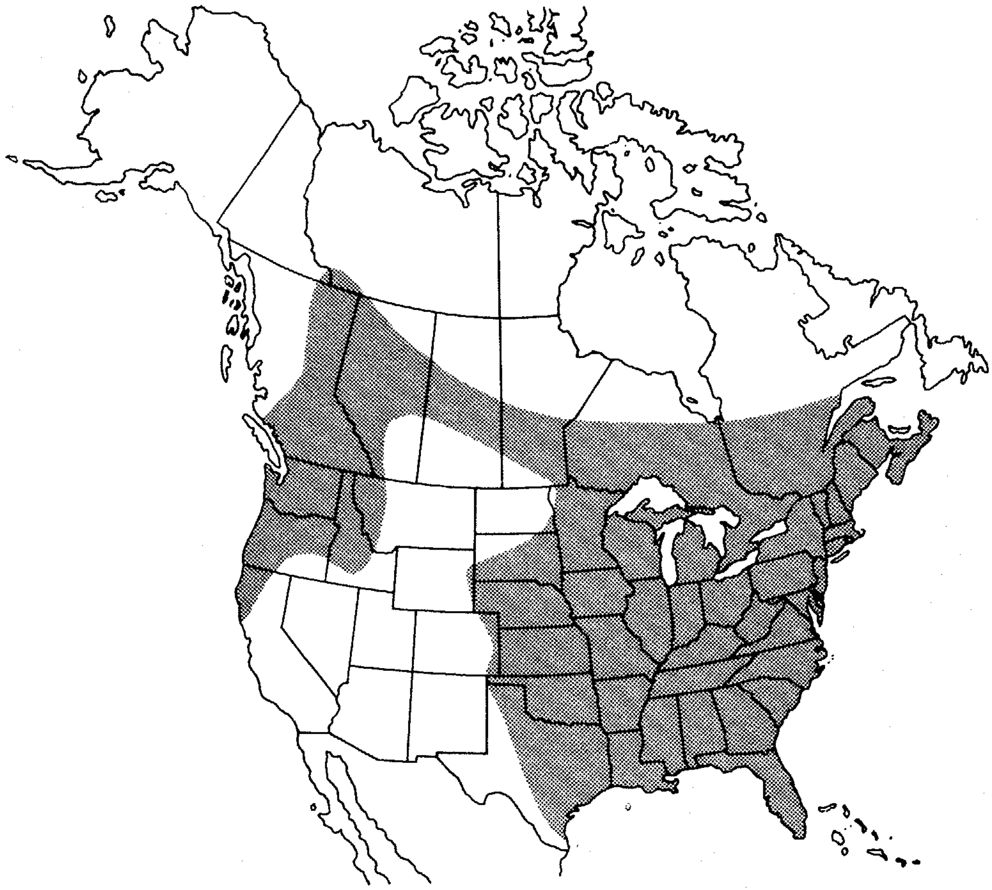


Figure 1. Approximate distribution of the barred owl [modified from Eckert (1974) and Hamer (unpubl.)].

This model has been formulated chiefly from data and information obtained in the midwestern and eastern portions of the barred owls' range. The majority of these investigations have been conducted in deciduous and mixed coniferous/deciduous forests. The size range used to define trees of suitable size to contain cavities for barred owl use has been extrapolated from these data. Because barred owls inhabit a wide variety of forest associations throughout North America, users of this model should modify the tree size constraints presented in the model to more accurately reflect mature tree size and cavity occurrence according to regional or habitat specific data.

Season. This model has been developed to evaluate reproductive habitat quality for the barred owl.

Cover types. This model was developed for application in the following cover types (terminology follows that of U.S. Fish and Wildlife Service 1981): Deciduous Forest (DF), Evergreen Forest (EF), and Palustrine, Forested Wetlands (PFO) (wetland terminology follows that of Cowardin et al. 1979).

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat required before an area will be occupied by a species. Specific information on the minimum habitat area required by the barred owl was not located in the literature. The species is restricted to forested cover types for shelter and reproductive purposes; however, many cover types are used for foraging if suitable perch sites are available. Therefore, minimum area of contiguous habitat (e.g., home range) does not directly relate to minimum size of forested habitat required for nest establishment. The literature alludes to the barred owls' preference for expansive woodlands for reproductive habitat. Barred owls probably do not do well in areas with only tens of hectares of forest, whereas they probably thrive in forests of hundreds to thousands of hectares (M.R. Fuller, Patuxent Wildlife Research Center, U.S. Fish and Wildlife Service, Laurel, MD; letter dated September 18, 1987). The minimum size of contiguous forest cover required for acceptable reproductive habitat is unknown.

Verification level. This HSI model provides information useful for impact assessment and habitat management. The model is a hypothesis of species-habitat relationships and does not reflect proven cause and effect relationships. Previous drafts of this model were reviewed by Dr. M.R. Fuller, U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, MD; Mr. T. Hamer, U.S. Forest Service, Mt. Baker Ranger District, Sedro Woolley, WA; and Dr. J.A. Jackson, Mississippi State University, Mississippi State, MS. Modifications and additional information provided as a result of these reviews have been incorporated into the model. Model output has not been evaluated against measures of barred owl habitat use or population density.

Model Description

Overview. Based on available literature, the most critical component of barred owl habitat appears to be availability of trees of sufficient size to provide cavities that are required for nesting. This model is based on the assumption that reproductive habitat is the most limiting characteristic of year-round barred owl habitat. If trees of sufficient size and numbers are present to ensure the availability of potential nest sites, then the cover and roosting requirements of the species also are assumed to be provided.

The availability and distribution of water does not appear to be a potentially limiting component of barred owl habitat, therefore these factors are not addressed in this HSI model. Several investigations of barred owl habitat relationships have shown the owls' use of forest stands that contain relatively open understories. It has been suggested that dense mid and understory vegetation inhibits the barred owls' ability to fly and effectively forage. This model is based on the assumption that mid and understory vegetative density has less influence in the definition of habitat quality for barred owls than do the characteristics of a forest stand that provide reproductive habitat (e.g., availability of cavities and the size and canopy density of overstory trees). It is assumed that barred owls will locate suitable foraging sites regardless of understory density at a specific location or within an individual stand. Therefore, the density and abundance of mid and understory vegetation is not addressed in this model.

This model will produce index values that are assumed to be proportional to a forest stand's ability to provide suitable reproductive habitat for barred owls. Stands that receive a 0.0 value are assumed to be indicative of unsuitable reproductive habitat due to small size class trees dominating the stand, an absence of suitable cavities, or relative sparseness. The potential of a stand for providing suitable reproductive habitat is assumed to correspond to increasing HSI values. When applied to areas larger than individual stands (e.g., management units, drainages), higher HSI values are assumed to correspond to greater overall reproductive habitat quality and a higher density of breeding pairs than can be expected in an equally sized area with a lower HSI value.

The following sections provide documentation of the logic and assumptions used to translate habitat information for the barred owl into the variables and equation used in the HSI model. Specifically, these sections cover (1) identification of variables, (2) definition and justification of the suitability levels of each variable, and (3) description of the assumed relationships between variables.

Reproduction component. High quality reproductive habitat for barred owls requires the presence of large size class, mature to old-growth, forest stands to provide nest cavities. Nests can be established in cavities within the boles of living or dead trees. Barred owls require relatively large cavities, therefore, large diameter trees have the greatest likelihood of containing cavities of sufficient size for use by the species. A precise count of the number of suitable tree cavities existing in a stand, or given area, would provide a more accurate indication of reproductive habitat quality for barred owls than would a surrogate measure of a stand's structural composition. This model, however, is based on the assumption that users will typically not have the time or resources to conduct intensive surveys to locate and count the number of cavities in a stand. Therefore, the reproductive component of this model is based on the assumption that the probability of the existence of suitable tree cavities in a stand will increase as the stand approaches maturity.

Several references in the preceding narrative have emphasized the number of snags per area required to support various population levels of barred owls. Barred owls will, however, nest in cavities within both living trees and snags. There also is some indication that cavities within living trees may provide nest sites superior to those in snags. This model is based on the assumption that dbh is the primary indicator of potential nest site quality. No distinction is made between the potential quality of living trees or snags as nest sites for barred owls.

Trees ≥51 cm dbh are believed to be of sufficient size to contain cavities of adequate dimensions for use by barred owls; however, most trees in this size class will not contain a suitable cavity. Therefore, it is assumed that as the number of trees (either living or snags) ≥51 cm dbh increases, the probability of the existence of suitable cavities also will increase. It is assumed that ≥2 trees/0.4 ha that are ≥51 cm dbh represents a sufficient number of trees to meet the nesting requirements of the barred owl (Figure 2). Stands that contain <2 trees/0.4 ha in this size class are assumed to be indicative of lower reproductive habitat quality due to the decreased probability of suitable cavities. The complete absence of trees ≥51 cm is assumed to reflect stands with minimum potential, but not totally unsuitable reproductive habitat, since barred owls may nest within trees of slightly smaller diameter, or abandoned nests of other raptors.

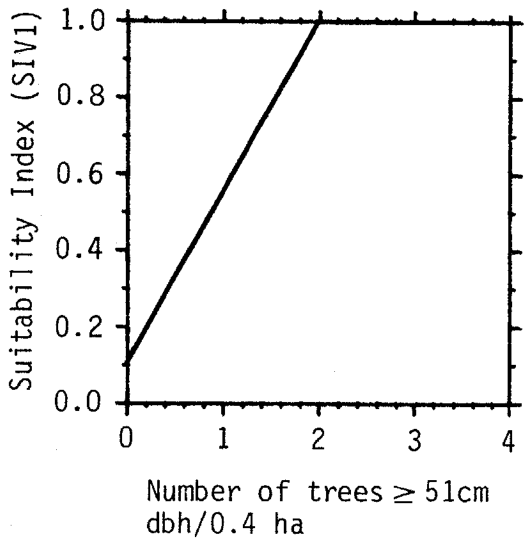


Figure 2. The relationship between the number of trees ≥51 cm dbh/0.4 ha and reproductive habitat quality for barred owls.

Reproductive habitat conditions are assumed to be enhanced as forest stands approach maturity and decadence. The characteristics of senescent stands are typically: a larger mean dbh of trees that compose the dominant overstory, decreased growth rates, and a heightened susceptibility to damage as a consequence of climatic extremes or insect or fungal infestations, resulting in a greater distribution and abundance of dying and dead trees than can be expected in younger, more vigorous stands (Spurr and Barnes 1980). A mean dbh of overstory trees of ≥51 cm is assumed to be indicative of a mature to old-growth forest stand. It can be assumed that the existence of suitable nest cavities will be greater in such stands. More importantly, a mean dbh of overstory trees ≥51 cm is assumed to be representative of mature forest stands that appear to be preferred by barred owls as reproductive habitat. Reproductive habitat quality for the barred owl is assumed to decline in response to a decrease in the mean dbh of trees composing the dominant overstory (Figure 3). Stands dominated by pole sized trees (12 to 22 cm for conifers, 12 to 28 cm for hardwoods) are assumed to have marginal value as reproductive habitat for the species due to the immature nature of the stand. Totally unsuitable reproductive habitat is assumed to be present when stands are dominated by sapling sized trees (dbh <12 cm).

Barred owls have been reported to prefer dense stands as reproductive habitat. Therefore, the density of the forest canopy is assumed to have a major influence on a stand's potential to provide suitable reproductive habitat. This model is based on the assumption that a stand will provide poor to unsuitable reproductive habitat, regardless of the presence of trees ≥51 cm, if the overall canopy closure of overstory trees is low. Optimum reproductive habitat is assumed to be present when overstory tree canopy cover is ≥60% (Figure 4). Overstory tree canopy closure <60% is assumed to be indicative of less suitable reproductive habitat due to the more open nature of the stand. Unsuitable reproductive habitat is assumed to exist when overstory tree canopy is ≤20% regardless of the size class of trees that compose the overstory.

HSI determination. The calculation of an HSI for the barred owl considers only the life requisite value calculated for reproductive habitat. Therefore, the HSI for the barred owl is equal to the reproduction suitability index (SIR) presented below.

$$HSI = SIR = (SIV1 \times SIV2)^{1/2} \times SIV3$$

The reproduction suitability index is based on the following suppositions. Barred owl reproductive habitat quality is assumed to be a function of the number of trees ≥51 cm dbh/0.4 ha (SIV1), the mean dbh of overstory trees (SIV2), and the canopy cover of overstory trees (SIV3). SIV1 and SIV2 are assumed to be equal and compensatory in defining reproductive habitat quality. Stands with at least two 51 cm dbh trees/0.4 ha and having a mean overstory tree dbh ≥51 cm represent ideal conditions. Stands with ≥2 51-cm dbh trees/0.4 ha but having a mean dbh of overstory trees <51 cm are assumed to be indicative of lower reproductive habitat quality as a result of the smaller diameter of overstory trees. SIV3 is assumed to directly modify the value calculated for SIV1 and SIV2. As a result of the barred owls' preference for selecting "dense" stands for establishment of nests, stands composed of large diameter overstory trees will be of lower value as barred owl reproductive habitat if the stand is relatively open, <60% canopy cover of overstory trees. Unsuitable reproductive habitat is assumed to be present when the canopy cover

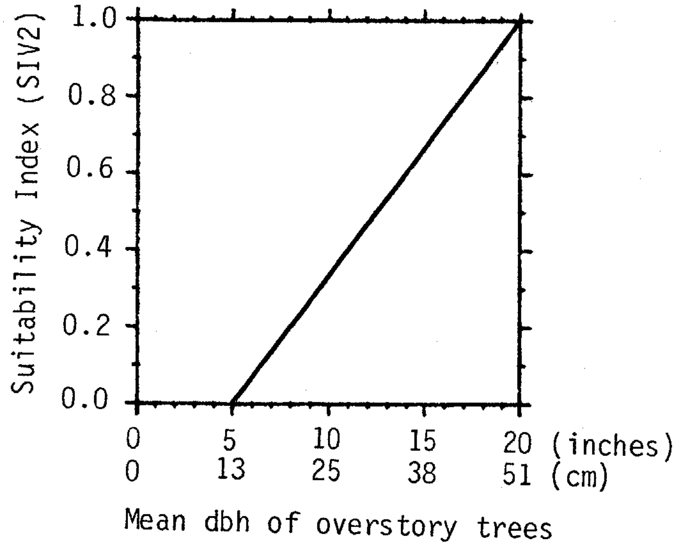


Figure 3. The relationship between mean dbh of overstory trees and reproductive habitat quality for barred owls.

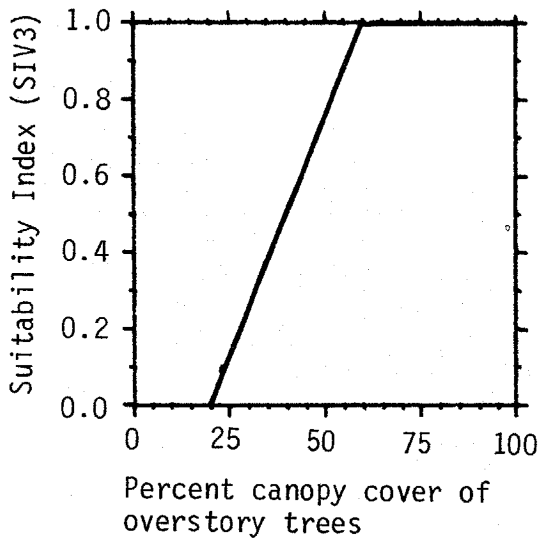


Figure 4. The relationship between percent canopy cover of overstory trees and reproductive habitat quality for barred owls.

of overstory trees is ≤20% regardless of overstory tree size. In summary, optimum reproductive habitat for barred owls can be characterized as a forest stand that has ≥2 51-cm dbh trees/0.4 ha, a mean overstory tree dbh of ≥51 cm, and an overstory canopy cover ≥60%.

Application of the Model

This model may be used to determine the HSI values for individual forest stands or for a number of forest stands that make up the total evaluation area. In situations where two or more stands are evaluated, an overall weighted HSI (weighted by area) can be determined by performing the following steps:

1. Stratify the evaluation area into forest or stand types.
2. Determine the area of each stand and the total area of the evaluation area.
3. Determine an HSI value for each stand in the evaluation area.
4. Multiply the area of each stand by its respective HSI value.
5. Add all products calculated in step 4 and divide the sum by the total area of all stands evaluated to obtain the weighted HSI value.

The steps outlined above are expressed by the following equation:

$$\text{Overall HSI (weighted by area)} = \frac{\sum_{i=1}^{n} HSI_i \, A_i}{\sum A_i}$$

where n = number of stands

HSI_i = HSI of stand i

A_i = area of stand i

Summary of model variables. Three habitat variables are used in this model to evaluate barred owl reproductive habitat quality. The relationship between habitat variables, cover types, life requisite value, and HSI are summarized in Figure 5. Definitions and suggested measurement techniques (Hays et al. 1981) for the variables used in the barred owl HSI model are provided in Figure 6.

Habitat variable	Cover types	Life requisite	
Number of trees ≥51 cm dbh/0.4 ha	DF,EF,PFO		
Mean dbh of overstory trees	DF,EF,PFO	Reproduction	HSI
Percent canopy cover of overstory trees	DF,EF,PFO		

Figure 5. Relationships of habitat variables, cover types, and life requisite values in the barred owl HSI model.

Variable (definition)	Cover types	Suggested technique
Number of trees ≥51 cm dbh/0.4 ha [number of trees, either living or snags, ≥51 cm (20 inches) diameter at breast height (1.4 m or 4.5 ft)/acre].	DF,EF,PFO	line intercept, quadrat, circular plot, remote sensing
Mean dbh of overstory trees [the mean diameter at breast height (1.4 m or 4.5 ft) of trees that are ≥80% of the height of the tallest tree in the stand].	DF,EF,PFO	line intercept, quadrat, circular plot, dbh tape
Percent canopy cover of overstory trees (the percent of the ground surface that is shaded by a vertical projection of the canopies of all trees that are ≥80% of the height of the tallest tree in the stand).	DF,EF,PFO	line intercept, quadrat, circular plot, remote sensing

Figure 6. Definitions of variables and suggested measurement techniques.

Model assumptions. The barred owl habitat model is based on the following assumptions.

1. The availability and quality of reproductive habitat is assumed to be the most limiting component of year-round barred owl habitat.

2. The probability of sufficient numbers of cavities suitable for barred owl use is assumed to be greater in mature and old-growth stands than in younger stands. Therefore, reproductive habitat quality is assumed to increase as forest stands approach maturity and decadence.

3. Trees with a dbh ≥51 cm are assumed to be of adequate size to contain cavities of dimensions suitable for barred owl use.

4. Densely forested stands, as reflected by percent canopy cover of overstory trees, are assumed to provide reproductive habitat of higher quality than less dense stands, regardless of the abundance of trees ≥51 cm dbh.

5. Based on measures of size and density of overstory trees and trees ≥51 cm, upland forests and forested wetlands are assumed to have equal potential as barred owl habitat. The availability and distribution of water is assumed to have no direct influence on the quality of reproductive habitat for the species.

6. Evergreen, deciduous, and stands of mixed composition are assumed to have equal potential as barred owl reproductive habitat.

7. Provided that they are ≥51 cm dbh, living trees and snags are assumed to have equal values as potential nest sites for barred owls.

8. Although barred owls have been reported to use abandoned raptor nests, the presence or absence of raptor nests is assumed to be inconsequential in the definition of barred owl reproductive habitat quality. It is assumed that the presence of raptor nests will not insure their use by barred owls and that the structural characteristics of a forest stand far outweigh the presence of raptor nests in the definition of reproductive habitat quality for barred owls.

SOURCES OF OTHER MODELS

No other models for the evaluation of barred owl habitat were located in the literature.

The barred owl and spotted owl (*Strix occidentalis*) are closely related and are considered by some authors to represent a superspecies (American Ornithologists' Union 1983). Laymon et al. (1985) developed a Habitat Suitability Index (HSI) model for evaluation of spotted owl habitat. The model is applicable to the Sierran Forest Province (as defined by Bailey 1978) and the Pacific Forest Province. The model is intended to evaluate year-round habitat quality based on the evaluation of average dbh of overstory trees, percent tree canopy closure, and tree canopy diversity.

Since this barred owl model has been formulated based on data gathered chiefly in the midwest and eastern portions of the species range, users in the Pacific Northwest may find it useful to compare the two models. The major difference in the models is that overstory trees with a dbh ≥90 cm are defined as optimum in the spotted owl model rather than ≥51 cm as defined in this model. In addition, a variable is included in the spotted owl model that is used to evaluate the structural composition of forest stands.

REFERENCES

American Ornithologists' Union. 1983. Check-list of North American birds, 6th ed. American Ornithologists' Union, Washington, DC. 877 pp.

Apfelbaum, S.I., and P. Seelbach. 1983. Nest tree, habitat selection, and productivity of seven North American raptor species based on the Cornell University nest record card program. Raptor Res. 17(4):97-113.

Applegate, R.D. 1975. Co-roosting of barred owls and common grackels. Bird-Banding 46(2):169-170.

Bailey, R.G. 1978. Descriptions of the ecoregions of the United States. U.S. Dept. Agric. Misc. Publ. No. 1391. 77 pp.

Bent, A.C. 1938. Life histories of North American birds of prey: Part 2. U.S. Natl. Mus. Bull. 170. Dover, NY. 482 pp.

Boxall, P.C., and P.H.R. Stepney. 1982. The distribution and status of the barred owl in Alberta. Can. Field-Nat. 96(1):46-50.

Caldwell, L.D. 1972. Diurnal hunting by a barred owl. Jack-pine Warbler 50(3):93-94.

Carmichael, D.B., Jr., and D.C. Guynn. 1983. Snag density and utilization by wildlife in the Upper Piedmont of South Carolina. Pages 107-110 in J.W. Davis, G.A. Goodwin, and R.A. Ockenfels, tech. coords. Snag habitat management: proceedings of the symposium. USDA For. Serv., Tech. Rep. RM99.

Carter, J.D. 1925. Behavior of the barred owl. Auk 42(2):443-444.

Cowardin, L.M., V. Carter, F.G. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish Wildl. Serv. FWS/OBS-79/31. 103 pp.

Devereux, J.G., and J.A. Mosher. 1982. Nesting habits of the barred owl in western Maryland. Maryland Birdlife 38(4):124-126.

______________. 1984. Breeding ecology of barred owls in the central Appalachians. Raptor Res. 18(2):49-58.

Dexter, R.W. 1978. Mammals utilized as food by owls in reference to the local fauna of northeastern Ohio. Kirtlandia 24:1-6.

Dunstan, T.C., and S.D. Sample. 1972. Biology of barred owls in Minnesota. Loon 44(4):111-115.

Earhart, C.M., and N.K. Johnson. 1970. Size, dimorphism, and food habits of North American owls. Condor 72(2):251-264.

Eckert, A.W. 1974. The owls of North America. Doubleday & Company, Inc., Garden City, New York. 278 pp.

Elody, B.J. 1983. Techniques for capturing, marking, monitoring, and habitat analysis for the barred owl in the Upper Peninsula of Michigan. M.S. Thesis. Michigan Technological University, Houghton. 103 pp.

Elody, B.J., and N.F. Sloan. 1985. Movements and habitat use of barred owls in the Huron Mountains of Marquette County, Michigan, as determined by radiotelemetry. Jack-pine Warbler 63(1):3-8.

Errington, P.L., and M. McDonald. 1937. Conclusions to the food habits of the barred owl in Iowa. Iowa Bird Life 7:47-49.

Evans, K.E., and R.N. Conner. 1979. Snag management. Pages 214-225 in R.M. DeGraaf and K.E. Evans, compilers. Management of north central and northeastern forests for nongame birds: workshop proceedings. USDA For. Serv. Gen. Tech. Rep. NC-51.

Fyfe, R.W. 1976. Status of Canadian raptor populations. Can. Field-Nat. 90:370-375.

Fuller, M.R. 1979. Spatiotemporal ecology of four sympatric raptor species. Ph.D. Dissertation. University Minnesota St. Paul. 396 pp.

Grant, J. 1966. The barred owl in British Columbia. Murrelet 47(2):39-45.

Hamel, P.B., H.E. LeGrand, Jr., M.R. Lennartz, and S.A. Gauthneaux. 1982. Bird-habitat relationships on southeastern forest land. USDA For. Serv. Gen. Tech. Rep. SE-22. 423 pp.

Hanebrink, E.L., A.F. Posey, and K. Sutton. 1979. A note on the food habits of selected raptors from northeastern Arkansas. Arkansas Acad. Sci. Proc. 33:79-80.

Hays, R.L., C.S. Summers, and W. Seitz. 1981. Estimating wildlife habitat variables. U.S. Fish Wildl. Serv. FWS/OBS-81/47. 111 pp.

Holgersen, N.E. 1974. Prey of the barred owl. Delmarva Ornithologist 9(2):30.

Johnson, D.H. 1980. Barred owls use nest box. Loon 52(4):193-194.

Johnson, D.H., and D.G. Follen, Sr. 1984. Barred owls and nest boxes. Raptor Res. 18(1):34-35.

Laymon, S.A., H. Salwasser, and R.H. Barrett. 1985. Habitat suitability index models: spotted owl. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.113). 14 pp.

Leder, J.E., and M.L. Walters. 1980. Nesting observations for the barred owl in western Washington. Murrelet 61(3):111-112.

LeDuc, P. 1970. The nesting ecology of some hawks and owls in southeastern Minnesota. Loon 42:48-62.

Marks, J.S., D.P. Hendricks, and V.S. Marks. 1984. Winter food habits of barred owls in western Montana. Murrelet 65(1):27-28.

McGarigal, K., and J.D. Fraser. 1984. The effect of forest stand age on owl distribution in southwestern Virginia. J. Wildl. Manage. 48(4):1393-1398.

Nicholls, T.H., and D.W. Warner. 1972. Barred owl habitat use as determined by radiotelemetry. J. Wildl. Manage. 36(2):213-224.

Soucy, L.J., Jr. 1976. Barred owl nest. N. Am. Bird Bander 1(2):68-69.

Spurr, S.H., and B.V. Barnes. 1980. Forest ecology. John Wiley and Sons, New York. 687 pp.

Taylor, A.L., Jr., and E.D. Forsman. 1976. Recent range extensions of the barred owl in western North America, including the first records for Oregon. Condor 78(4):560-561.

U.S. Fish and Wildlife Service. 1981. Standards for the development of habitat suitability index models. 103 ESM. U.S. Fish Wildl. Serv., Div. Ecol. Serv. n.p.

Wilson, K.A. 1938. Owl studies at Ann Arbor, Michigan. Auk 55:187-197.

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. Biological Report 82(10.143)	2.	3. Recipient's Accession No.

4. Title and Subtitle

Habitat Suitability Index Models: Barred Owl

5. Report Date September 1987

6.

7. Author(s)

Arthur W. Allen

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

National Ecology Research Center
U.S. Fish and Wildlife Service
Drake Creekside One Bldg.
2627 Redwing Road
Fort Collins, CO 80526-2899

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.

(C)

(G)

12. Sponsoring Organization Name and Address

National Ecology Research Center
Research and Development
Fish and Wildlife Service
Department of the Interior
~~Washington, DC 20240~~

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for the barred owl (Strix varia). The model consolidates habitat use information into a framework appropriate for field application, and is scaled to produce an index between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). HSI models are designed to be used with Habitat Evaluation Procedures previously developed by U.S. Fish and Wildlife Service.

17. Document Analysis a. Descriptors

Birds
Wildlife
Habitability
Mathematical models

b. Identifiers/Open-Ended Terms

Barred owl
Strix varia
Habitat suitability

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release unlimited	Unclassified	17
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI-Z39.18) See Instructions on Reverse

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

Great Trinity Forest Management Plan

Wildlife Management

Carolina Chickadee

(Poecile carolinensis)

Carolina Chickadee
(*Poecile carolinensis)*

Carolina chickadee is a small, nonmigratory bird which occurs in the southeastern United States. It is very similar to the black-capped chickadee (*Parus atricapillus*) in its habits and appearance; therefore, the black-capped chickadee habitat suitability index model was used in this report. (Mostrom et al. 2002)

Food

This species is an insectivorous gleaner whose diet in the winter consists of 50% insects and 50% plant matter such as seeds and fruits. The rest of the year the diet consists of 80-90% insects such as spiders and caterpillars. (Schroeder 1983, Mostrom et al. 2002)

Water

Free water is needed but usually this is easily met with surface water. (Schroeder 1983)

Habitat

It inhabits a wide variety of wooded areas, such as parks and suburban sites to riparian hardwood forest and upland mixed pine-hardwood forest. Mostrom et al (2002) states that this species habitat requirements include soft/rotten wood or natural cavities and a multiple-layer forest with a healthy shrub, midstory and overstory canopy. Winter flock ranges can range from 3.8 ha to 14.6 ha (9.4 - 36 ac) while the territory in the breeding season can range from 1.6 ha to 6.9 ha (4 - 17.1 ac). (Schroeder 1983, Mostrom et al. 2002)

Reproduction

This species is a cavity nester which will excavate its own nest in rotten or soft wood but will also use natural cavities, woodpecker cavities and nest boxes. It usually nests near an open area in trees with an average diameter of 11.4 cm (4.5 in) and a minimum diameter of 10.2 cm (4 in). It will also nest in tree stubs which range from 10 to 15 cm (3.9 to 5.9 in). The height of the cavity may range from 0.3 to 12.2 m (1 to 40 ft) but Mostrom et al. (2002) reported an average height of 2.8 m (9.2 ft) from the ground. (Schroeder 1983, Mostrom et al. 2002)

Management

When managing for Carolina chickadee it is important to provide adequate food which can be measured by (a) tree canopy closure and average height of overstory, or (b) with canopy volume of trees per area of ground surface. If the first method is used then the optimum conditions occur at 50 - 75% tree canopy closure and when the average height of overstory trees is greater than 15 m (49.2 ft). Since insect abundance is positively correlated with the canopy volume, the second method is optimal and the best conditions occur at greater than 10.2m^3 of foliage/m^2 of ground surface (33.5 ft^3 of foliage/ft^2). If food is inadequate then feeders may be used until the site is more productive. Another important habitat factor is reproductive cover in the form of snags. There should be more than 2 snags per 0.4 ha (1 ac) that have a dbh of 10 to 25 cm (4 to 10 in). If an insufficient number of snags are present then nest boxes may be used. This species also will use plastic or artificial snags that are 7.6 - 10.2 cm (3-5 in) in diameter and have an entrance diameter of 2.9 to 3.2 cm (1.1-1.3 in). (Schroeder 1983, Mostrom et al. 2002)

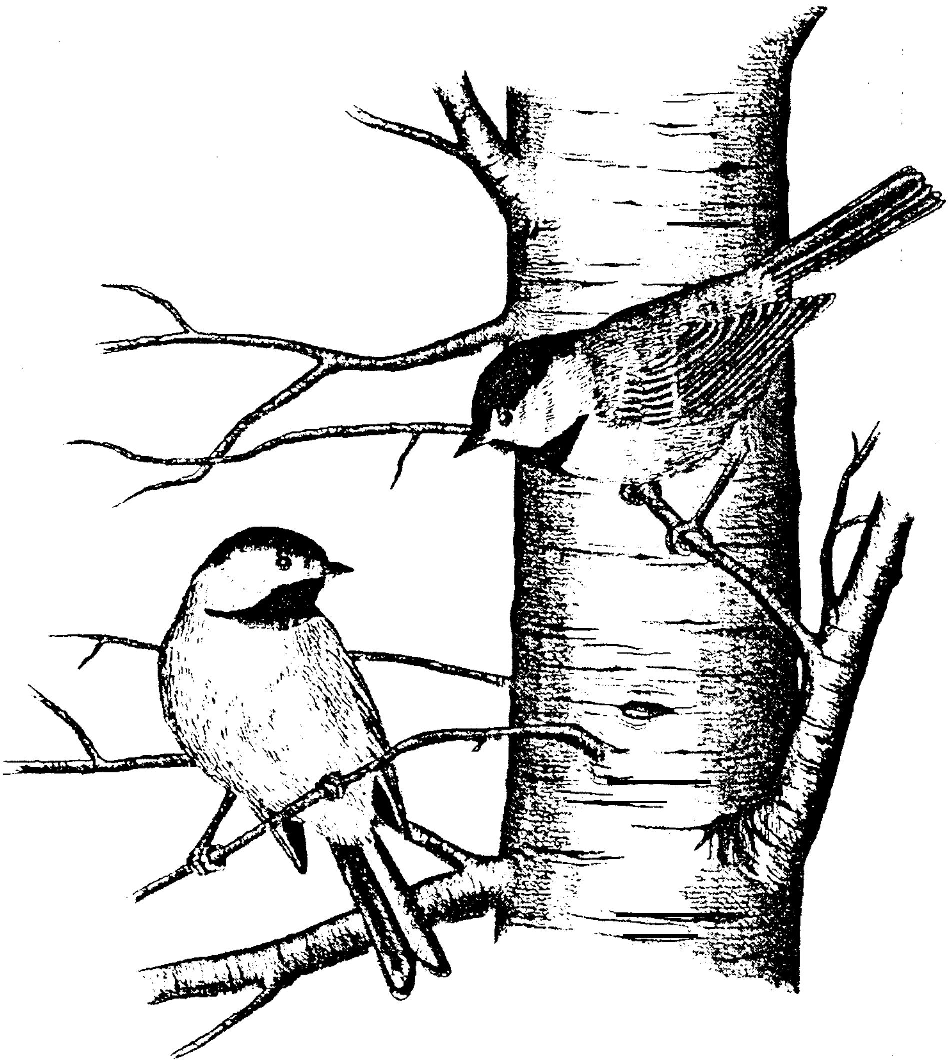
Literature Cited

Mostrom, A. M., R. L. Curry, and B. Lohr. 2002. Carolina Chickadee (*Poecile carolinensis*).*In* The Birds of North America, No. 636 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Schroeder, R.L. 1983. Habitat Suitability Index Models: Black-capped Chickadee. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.37. 10 pp.

FWS/OBS-82/10.37
APRIL 1983

HABITAT SUITABILITY INDEX MODELS: BLACK-CAPPED CHICKADEE



Fish and Wildlife Service

U.S. Department of the Interior

This model is designed to be used by the Division of Ecological Services in conjunction with the Habitat Evaluation Procedures.

FWS/OBS-82/10.37
April 1983

HABITAT SUITABILITY INDEX MODELS: BLACK-CAPPED CHICKADEE

by

Richard L. Schroeder
107 N. Hollywood
Fort Collins, CO 80521

Project Officer

R. Charles Solomon
Western Energy and Land Use Team
Drake Creekside Building One
U.S. Fish and Wildlife Service
2627 Redwing Road
Fort Collins, CO 80526

Western Energy and Land Use Team
Division of Biological Services
Research and Development
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

PREFACE

This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for HSI models that follow. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model Section documents a habitat model and information pertinent to its application. The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The application information includes descriptions of the geographic ranges and seasonal application of the model, its current verification status, and a listing of model variables with recommended measurement techniques for each variable.

In essence, the model presented herein is a hypothesis of species-habitat relationships and not a statement of proven cause and effect relationships. Results of model performance tests, when available, are referenced. However, models that have demonstrated reliability in specific situations may prove unreliable in others. For this reason, feedback is encouraged from users of this model concerning improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning. Please send suggestions to:

Habitat Evaluation Procedures Group
Western Energy and Land Use Team
U.S. Fish and Wildlife Service
2627 Redwing Road
Ft. Collins, CO 80526

CONTENTS

ACKNOWLEDGMENTS

We gratefully acknowledge Peter Merritt for his review of this habitat model. Funds for the development of this model were provided by the U.S. Fish and Wildlife Service Regional Office in Portland. Publication costs of this model were partially paid for by the U.S. Army Corps of Engineers. The cover of this document was illustrated by Jennifer Shoemaker. Word processing was provided by Carolyn Gulzow and Dora Ibarra.

BLACK-CAPPED CHICKADEE (*Parus atricapillus*)

HABITAT USE INFORMATION

General

The black-capped chickadee (*Parus atricapillus*) inhabits wooded areas in the northern United States, Canada, and the higher elevations of mountains in southern Appalachia (Tanner 1952; Brewer 1963; Merritt 1981). The black-capped chickadee nests in cavities in dead or hollow trees (Nickell 1956), in a variety of forest types (Dixon 1961).

Food

Black-capped chickadees are insectivorous gleaners (Brewer 1963; Sturman 1968b) that select prey in proportion to its availability (Brewer 1963). Insect food is mostly gleaned from tree bark on twigs, branches, and boles; or from the foliage, fruits, and flowers of trees (Brewer 1963). Caterpillars are an important food for nestling chickadees (Odum 1942; Kluyver 1961; Sturman 1968a). Insect and spider eggs make up a large portion of the winter diet, and, although the use of plant material for food is low during much of the year, seeds of trees and shrubs may account for about half of the winter diet (Martin et al. 1961). Seeds of weedy plants, such as giant ragweed (*Ambrosia* spp.), are favorite winter foods (Fitch 1958).

Black-capped chickadees are versatile in their foraging habits and forage from the ground to the tree tops in a variety of habitats, although they prefer to forage at low or intermediate heights in trees and shrubs (Odum 1942). Chickadees in British Columbia showed a preference for foraging within 1.5 m (5.0 ft) of the ground (Smith 1967).

Black-capped chickadees in western Washington selected their territories before the amount of insect food (especially caterpillars) was apparent, and it appeared that canopy volume of trees was the proximate cue used by the chickadees to determine potential food supply, since chickadee abundance showed a strong positive correlation with canopy volume (Sturman 1968a). Caterpillars eat foliage and their abundance should vary directly with total foliage weight. There was a strong positive correlation between total foliage weight and canopy volume, and, hence, canopy volume provided a good estimate of potential insect abundance. The highest chickadee densities occurred at canopy volumes of about 10.2 m^3 of foliage/l m^2 of ground surface (33.5 ft^3/ft^2).

Water

Drinking water requirements are met with surface water and snow (Odum 1942).

Cover

The black-capped chickadee occurs in both deciduous and evergreen forests in the eastern United States, although it is restricted to deciduous forests along streams in the Northern Great Plains, northern Rocky Mountains, and Great Basin areas (Dixon 1961). In some areas where the ranges of the black-capped chickadee and Carolina chickadee (P. carolinensis) come together, apparently suitable habitat exists where neither chickadee occurs (Tanner 1952; Brewer 1963; Merritt 1981). Deciduous forest types are preferred in western Washington (Sturman 1968a) and commonly used in Oregon (Gabrielson and Jewett 1940). Fall and winter roosts in New York were mostly on dense conifer branches, with some use of cavities (Odum 1942). Black-capped chickadees in Oregon and Washington excavated winter roost cavities in snags (Thomas et al. 1979). Winter roosts in deciduous forests of Minnesota were on the branches of trees and bushes that had retained their foliage (Van Gorp and Langager 1974).

Black-capped chickadee populations in Kansas tended to concentrate along edges between forest and early successional areas (Fitch 1958). The availability of suitable tree cavities for roosting may have been a limiting factor in this study area.

Reproduction

The black-capped chickadee nests in a cavity, usually in a dead or hollow tree (Nickell 1956). The presence of available nest sites, or trees that could be excavated, appeared to determine the chickadee's choice of nesting habitat. Two important factors affecting the use of stub trees in Michigan were height and the suitability of the tree for excavation (Brewer 1963). Willows (Salix spp.), pines (Pinus spp.), cottonwoods and poplars (Populus spp.), and fruit trees of the genera Pyrus and Prunus are frequently chosen for nest sites (Brewer 1961).

Black-capped chickadees are only able to excavate a cavity in soft or rotten wood (Odum 1941a, b). Trees with decayed heartwood, but firm sapwood, are usually chosen (Brewer 1961). Black-capped chickadees almost always do some excavation at the nest site (Tyler 1946), although they will use existing woodpecker holes, natural cavities, man-made nest boxes, and open topped fence posts (Nickell 1956). The average tree diameter at nest sites was 11.4 cm (4.5 inches), and preferred tree stubs apparently ranged from 10 to 15 cm (3.9 to 5.9 inches) in diameter (Brewer 1963). The minimum dbh of cavity trees used by black-capped chickadees is 10.2 cm (4 inches) (Thomas et al. 1979). Heights of 18 nests in New York ranged from 0.3 to 12.2 m (1 to 40 ft), although only three nests were higher than 4.6 m (15 ft) and 11 nests were under 3.0 m (10 ft) (Odum 1941b).

Nests in New York were usually located in open areas, commonly in young forests, hedgerows, or field borders (Odum 1941a). Willow, alder (Alnus spp.) and cottonwood trees were common nest trees in Washington (Jewett et al. 1953). Black-capped chickadees used second growth alder for nesting sites in British Columbia (Smith 1967).

Interspersion

Black-capped chickadees maintain a territory during the breeding season and flock in the winter months (Odum 1941b; Stefanski 1967). Territory size during nest building in Utah averaged 2.3 ha (5.8 acres) (Stefanski 1967).

Territory size in New York varied from 3.4 ha to 6.9 ha (8.4 to 17.1 acres), with an average size of 5.3 ha (13.2 acres) (Odum 1941a). The larger terri-tories were in open or sparsely wooded country; the size of the territory decreased as the nesting period progressed. The mean home range size of winter flocks was 9.9 ha (24.4 acres) in Kansas (Fitch 1958), 15.0 ha (37 acres) in Michigan (Brewer 1978), and 14.6 ha (36 acres) in New York (Odum 1942) and in Minnesota (Ritchison 1979).

Black-capped chickadees nesting on forest islands in central New Jersey did not nest in forests less than 2 ha (4.8 acres) in size (Galli et al. 1976). However, this apparent dependency on a minimum size forest may have been due to a lack of nesting cavities.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model was developed for the entire breeding range of the-black-capped chickadee.

Season. This model was developed to evaluate the breeding season habitat needs of the black-capped chickadee.

Cover types. This model was developed to evaluate habitat in Deciduous Forest (DF), Evergreen Forest (EF), Deciduous Forested Wetland (DFW), and Evergreen Forested Wetland (EFW) areas (terminology follows that of U.S. Fish and Wildlife Service 1981). It should be noted that, although the chickadee occurs in both deciduous and evergreen forests over much of its range, apparently there are geographic differences in use of cover types that limit the use of evergreen forests in parts of its range. Users should be familiar with the chickadee's major cover type preferences in their particular area before applying this model.

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before an area will be occupied by a species. Although Galli et al. (1976) report that black-capped chickadees may be dependent on certain forest sizes, other studies state that these chickadees will nest in hedgerows and field borders. This model assumes that forest size is not an important factor in assessing habitat suitability for the black-capped chickadees.

Verification level. Previous drafts of this model were reviewed by Peter Merritt, and his specific comments have been incorporated into the current draft (Merritt, pers. comm.).

Model Description

Overview. This model considers the ability of the habitat to meet the food and reproductive needs of the black-capped chickadee as an indication of overall habitat suitability. Cover needs are assumed to be met by food and reproductive requirements and water is assumed not to be limiting. The food component of this model assesses vegetation conditions, and the reproduction component assesses the abundance of suitable snags. The relationship between habitat variables, life requisites, cover types, and the HSI for the black-capped chickadee is illustrated in Figure 1.

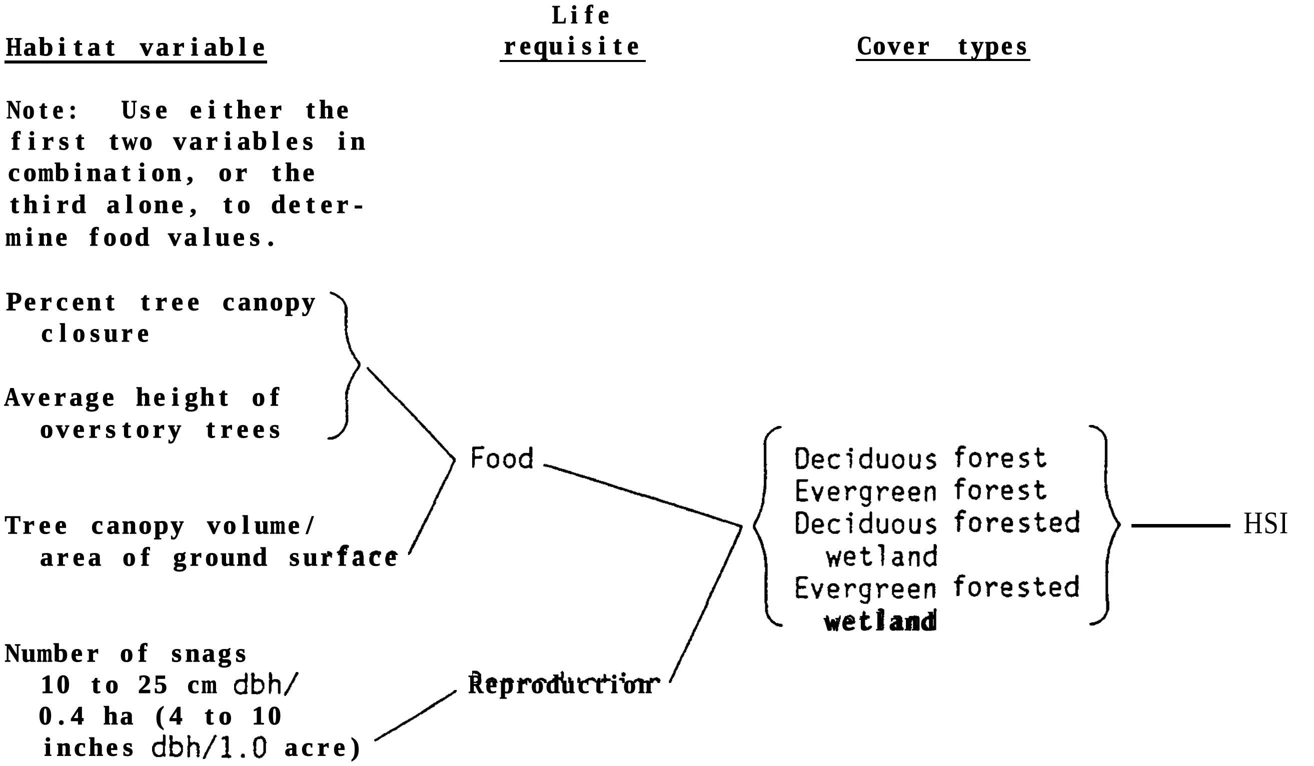


Figure 1. Relationship of habitat variables, life requisites, and cover types in the black-capped chickadee model.

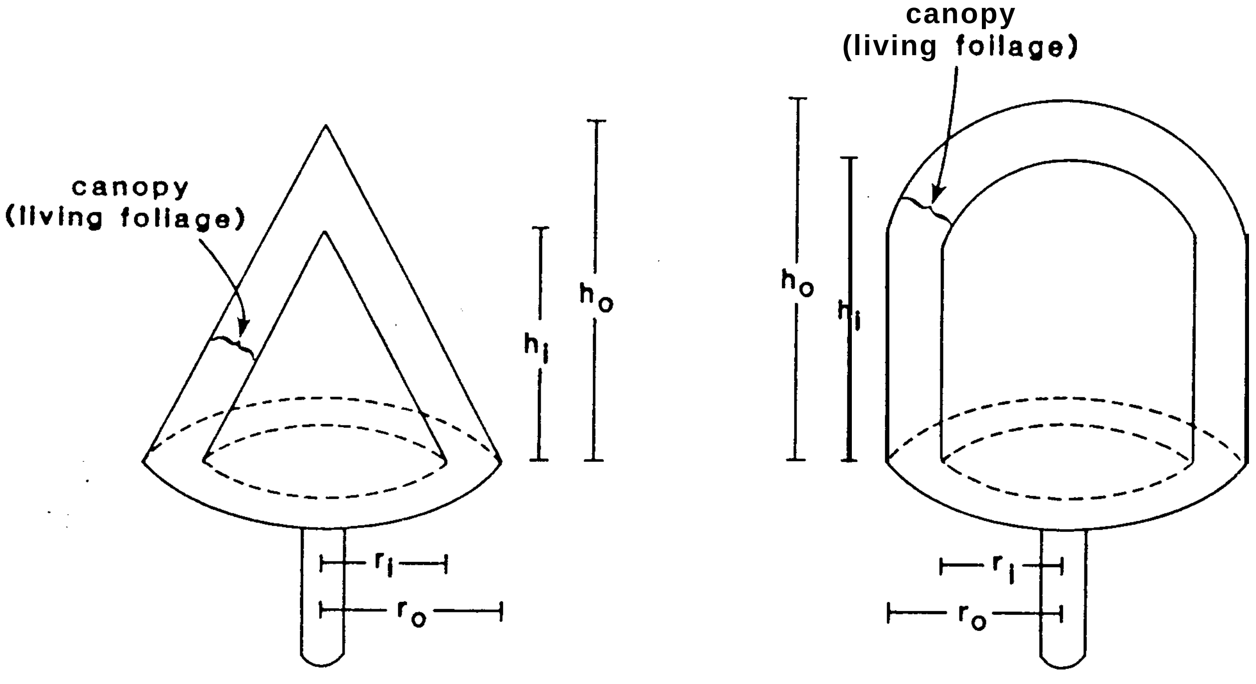
The following sections provide a written documentation of the logic and assumptions used to interpret the habitat information for the black-capped chickadee in order to explain the variables and equations that are used in the HSI model. Specifically, these sections cover the following: (1) identification of variables that will be used in the model; (2) definition and justification of the suitability levels of each variable; and (3) description of the assumed relationship between variables.

Food component. The majority of the year-round food supply of the black-capped chickadee is associated with trees. It is assumed that an accurate assessment of food suitability for the chickadee can be provided by a measure of either: (1) tree canopy closure and the average height of overstory trees; or (2) canopy volume of trees per area of ground surface. It is assumed that optimum canopy closures occur betwen 50 and 75%. A completely closed canopy will have less than optimum value due to an assumed lack of foliage in the middle and lower canopy layers. It is assumed that optimum habitats contain overstory trees 15 m (49.2 ft) or more in height. Habitats with a low canopy closure can provide moderate suitability for black-capped chickadees if tree heights are optimum. Likewise, habitats with short trees may have moderate suitability if canopy closures are optimum.

The canopy volume of an individual tree is equal to the area occupied by the living foliage of that tree, as shown in Figure 2 for deciduous and coniferous trees. Optimum canopy volume per area of ground surface exceeds 10.2 m^3 of foliage/m^2 of ground surface (33.5 ft^3 of foliage/ft^2 of ground surface). Suitability will decrease to zero as canopy volume approaches zero.

The field user should measure either: (1) tree canopy closure and tree height; or (2) tree canopy volume per area of ground surface. Tree canopy closure and tree height measurements are probably the most rapid method to assess food suitability. However, the suitability levels of these variables were not based on strong data sources. The suitability levels of tree canopy volume were based on data from Sturman (1968a).

Reproduction component. Black-capped chickadees nest primarily in small dead or hollow trees and can only excavate a cavity in soft or rotten wood. Therefore, reproduction suitability is assumed to be related to the abundance of small snags. It is assumed that snags between 10 and 25 cm (4 and 10 inches) dbh are required. Thomas et al. (1979) and Evans and Conner (1979) provide methods to estimate the number of snags required for cavity nesting birds. Assuming a territory size of 2.4 ha (6.0 acres) and a need for one cavity per year per chickadee pair, the method of Thomas et al. (1979) estimates that optimum habitats provide 5.9 snags/ha (2.4/acre), and the method of Evans and Conner (1979) estimates that 4.1 snags are needed per ha (1.67/acre) to provide optimum conditions. This model assumes that optimum suitability exists when there are five or more snags of the proper size per ha (2/acre), and that suitability will decrease to zero as the number of snags approaches zero.



CONIFEROUS

$$CV = \pi/3(h_o r_o^2 - h_i r_i^2)$$

DECIDUOUS

$$CV = 2\ \pi/3(h_o r_o^2 - h_i r_i^2)$$

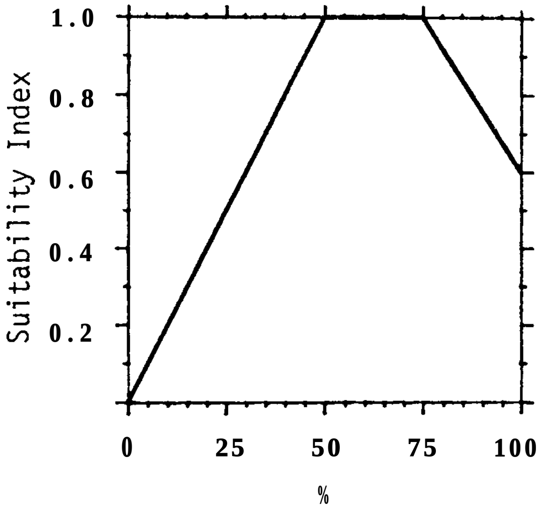
where: h_i = inner height
h_o = outer height
r_i = inner radius
r_o = outer radius

Figure 2. Tree shapes assumed and formulae used to calculate canopy volume (CV). (From Sturman 1968a).

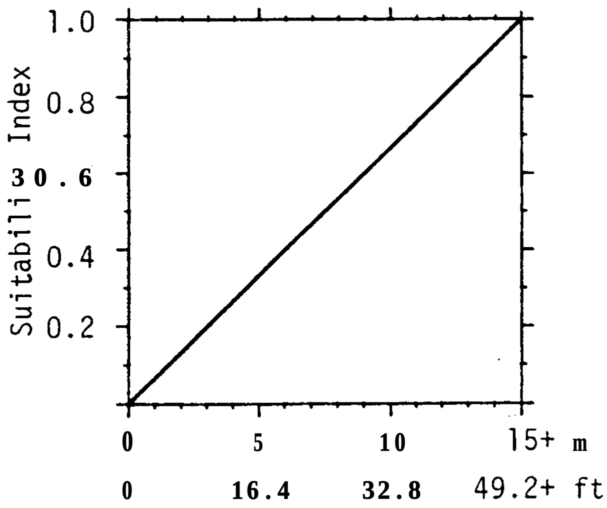
Model Relationships

Suitability Index (SI) graphs for habitat variables. This section contains SI graphs that illustrate the habitat relationships described in the previous section.

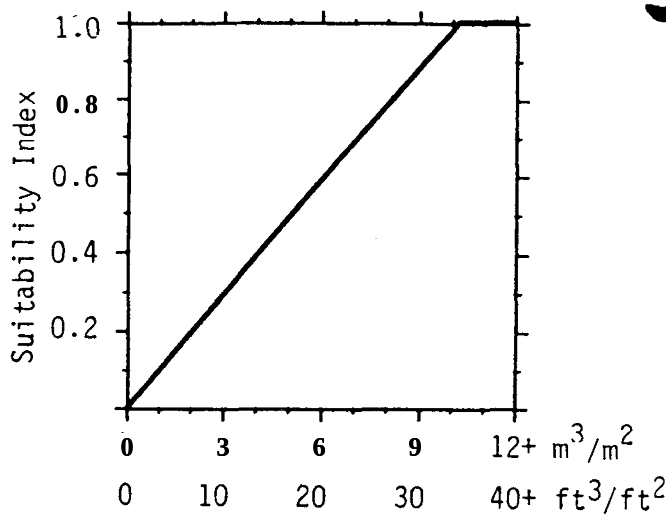
Cover type	Variable		Suitability graph
DF,EF, DFW,EFW	V_1	Percent tree canopy closure.	



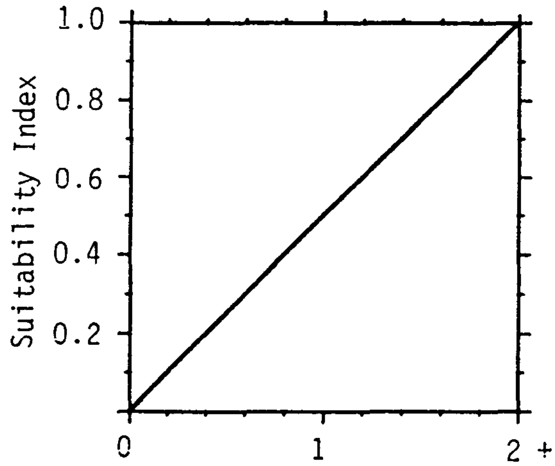
Cover type	Variable		Suitability graph
DF,EF, DFW,EFW	V_2	Average height of overstory trees.	



DF,EF, DFW,EFW — V_3 — Tree canopy volume/area of ground surface.



DF,EF, DFW,EFW — V_4 — Number of snags 10 to 25 cm dbh/0.4 ha (4 to 10 inches dbh/1.0 acre).



Equations. In order to determine life requisite values for the black-capped chickadee, the SI values for appropriate variables must be combined through the use of equations. A discussion and explanation of the assumed relationships between variables was included under Model Description, and the specific equations in this model were chosen to mimic these perceived biological relationships as closely as possible. The suggested equations for obtaining food and reproduction values are presented below.

Life requisite	Cover type	Equation
Food	DF,EF,DFW,EFW	$(V_1 \times V_2)^{1/2}$ or V_3 (See page 5 for discussion on which to use)
Reproduction	DF,EF,DFW,EFW	V_4

HSI determination. The HSI for the black-capped chickadee is equal to the lowest life requisite value.

Application of the Model

Definitions of variables and suggested field measurement techniques (from Hays et al. 1981, unless otherwise noted) are provided in Figure 3.

Variable (definition)		Cover types	Suggested technique
V_1	Percent tree canopy closure [the percent of the ground surface that is shaded by a vertical projection of the canopies of all woody vegetation taller than 5.0 m (16.5 ft)].	DF,EF,DFW,EFW	Line intercept
V_2	Average height of overstory trees (the average height from the ground surface to the top of those trees which are ≥ 80 percent of the height of the tallest tree in the stand).	DF,EF,DFW,EFW	Graduated rod, trigonometric hypsometry
V_3	Tree canopy volume/ area of ground surface (the sum of the volume of the canopies of each tree sampled divided by the total area sampled).	DF,EF,DFW,EFW	Quadrat and refer to Figure 2 on page 6

Figure 3. Definitions of variables and suggested measurement techniques.

Variable (definition)		Cover types	Suggested technique
V_4	Number of snags 10 to 25 cm dbh/0.4 ha (4 to 10 inches dbh/1.0 acre) [the number of standing dead trees or partly dead trees in the size class indicated that are at least 1.8 m (6 ft) tall. Trees in which at least 50% of the branches have fallen, or are present but no longer bear foliage, are to be considered snags].	DF,EF,DFW,EFW	Quadrat

Figure 3. (concluded).

SOURCES OF OTHER MODELS

Sturman (1968a) developed a multiple regression model for the black-capped chickadee in western Washington in which the canopy volume of trees accounted for 79.6% of the variation in chickadee abundance. Canopy volume of bushes and canopy volume of midstory trees were the next two most important variables, and their addition into the regression accounted for over half of the residual variation remaining after the canopy volume of trees was entered.

REFERENCES

Brewer, R. 1961. Comparative notes on the life history of the Carolina chickadee. Wilson Bull. 73(4):348-378.

_________. 1963. Ecological and reproductive relationships of black-capped and Carolina chickadees. Auk 80(1):9-47.

_________ 1978. Winter home ranges of black-capped chickadees in southern Michigan oak forest. Jack-Pine Warbler 56(2):96-98.

Dixon, K. L. 1961. Habitat distribution and niche relationships in North American species of Parus. Pages 179-216 in W. F. Blair, ed. Vertebrate speciation. Univ. Texas Press, Austin.

Evans, K. E., and R. N. Conner. 1979. Snag management. Pages 215-225 in R. M. DeGraaf, tech. coord. Management of north central and northeastern forests for nongame birds. U.S. Dept. Agric., For. Serv. Gen. Tech. Rep. NC-51.

Fitch, H. H. 1958. Home ranges, territories, and seasonal movements of vertebrates of the Natural History Reservation. Univ. Kansas Publ. Mus. Nat. Hist. 11(3):63-326.

Gabrielson, I. N., and S. G. Jewett. 1940. Birds of Oregon. Oreg. State Coll., Corvallis. 650 pp.

Galli, A. E., C. F. Leck, and R. T. T. Forman. 1976. Avian distribution patterns in forest islands of different sizes in central New Jersey. Auk 93(2):356-364.

Hays, R. L., C. S. Summers, and W. Seitz. 1981. Estimating wildlife habitat variables. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-81/47. 111 pp.

Jewett, S. G., W. P. Taylor, W. T. Shaw, and J. W. Aldrich. 1953. Birds of Washington State. Univ. Washington Press, Seattle. 767 pp.

Kluyver, H. N. 1961. Food consumption in relation to habitat in breeding chickadees. Auk 78(4):532-550.

Martin, A. C., H. S. Zim, and A. L. Nelson. 1961. American wildlife and plants - a guide to wildlife food habits. Dover Publ., Inc., NY. 500 pp.

Merritt, P. G. 1981. Narrowly disjunct allopatry between black-capped and Carolina chickadees in northern Indiana. Wilson Bull. 93(1):54-66.

__________ Personal communication (letter dated 8 November, 1982). Univ. Miami, Coral Gables, Florida.

Nickell, W. P. 1956. Nesting of the black-capped chickadee in the southern peninsula of Michigan. Jack-Pine Warbler 34(4):127-138.

Odum, E. P. 1941a. Annual cycle of the black-capped chickadee - I.- Auk 58(3):314-333.

__________. 1941b. Annual cycle of the black-capped chickadee - II. Auk 58(4):518-535.

__________. 1942. Annual cycle of the black-capped chickadee - III. Auk 59(4):499-531.

Ritchison, G. 1979. Social organization in winter flocks of black-capped chickadees. Loon 51(3):121-126.

Smith, S. M. 1967. Seasonal changes in the survival of the black-capped chickadee. Condor 69(4):344-359.

Stefanski, R. A. 1967. Utilization of the breeding territory in the black-capped chickadee. Condor 69(3):259-267.

Sturman, W. A. 1968a. Description and analysis of breeding habitats of the chickadees, Parus atricapillus and P. rufescens. Ecology 49(3):418-431.

______________ 1968b. The foraging ecology of Parus atricapillus and P. rufescens in the breeding season, with comparisons with other species of Parus. Condor 70(4):309-322.

Tanner, J. T. 1952. Black-capped and Carolina chickadees in the southern Appalachian mountains. Auk 69:407-424.

Thomas, J. W., R. G. Anderson, C. Maser, and E. L. Bull. 1979. Snags. Pages 60-77 in J. W. Thomas, tech. ed. Wildlife habitats in managed forests - the Blue Mountains of Oregon and Washington. U.S. Dept. Agric., For. Serv. Agric. Handb. 553.

Tyler, W. M. 1946. Black-capped chickadee. Pages 322-339 in A. C. Bent, ed. -Life histories of North American jays, crows, and titmice. U. S. Natl. Mus. Bull. 191.

U.S. Fish and Wildlife Service. 1981. Standards for the development of habitat suitability index models. 103 ESM. U.S. Dept. Int., Fish Wildl. Serv., Div. Ecol. Serv. n.p.

Van Gorp, B., and J. Langager. 1974. Winter roosting habits of the black-capped chickadee. Loon 46(2):85-86.

JO272 -101

REPORT DOCUMENTATION PAGE

1. REPORT NO. FWS/OBS-82/10.37	2.	3. Recipient's Accession No.
4. Title and Subtitle: Habitat Suitability Index Models: Black-capped Chickadee		5. Report Date: April 1983
		6.
7. Author(s): Richard L. Schroeder		8. Performing Organization Rept. No.
9. Performing Organization Name and Address: Habitat Evaluation Procedures Group Western Energy and Land Use Team U.S. Fish and Wildlife Service Drake Creekside Building One 2627 Redwing Road Fort Collins, CO 80526		10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address: Western Energy and Land Use Team Division of Biological Services Research and Development Fish and Wildlife Service Washington, DC 20240		13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

A review and synthesis of existing information was used to develop a habitat model for the black-capped chickadee (*Parus atricapillus*). The model is scaled to produce an index of habitat suitability between 0 (unsuitable habitat) and 1 (optimally suitable habitat) for areas of the continental United States. Habitat suitability indexes are designed for use with Habitat Evaluation Procedures previously developed by the U.S. Fish and Wildlife Service.

17. Document Analysis a. Descriptors

Mathematical models, Wildlife, Birds, Habitability.

b. Identifiers/Open-Ended Terms

Black-capped chickadee
Parus atricapillus
Habitat Suitability Indexes (HSI)

c. COSATI Field/Group

18. Availability Statement: Release Unlimited	19. Security Class (This Report): UNCLASSIFIED	21. No. of Pages: 12
	20. Security Class (This Page): UNCLASSIFIED	22. Price

(See ANSI-Z39.18) See Instructions on Reverse

OPTIONAL FORM 272 (L-77) (Formerly NTIS-35) Department of Commerce

U.S. GOVERNMENT PRINTING OFFICE: 1983—679-517/293 REGION NO. 8

DEPARTMENT Of THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving thaenvironmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

Great Trinity Forest Management Plan

Wildlife Management

Eastern Cottontail

(Sylvilagus floridanus)

Eastern Cottontail
(*Sylvilagus floridanus*)

This "is the most widely distributed cottontail in North America" (Allen 1982). It occurs from southern Canada to South America and it even seems to be expanding its range northward. Not only is this species a principal game species in eastern United States, it is also heavily preyed upon by such species as foxes, bobcats (*Lynx rufus*), hawks, owls and coyotes (*Canis latrans*). (Allen 1982, Yarrow 1999)

Food

The cottontail consumes "nearly every kind of grass, succulent herb, or flowering plant, native or introduced," (Allen 1982). This species will even consume the bark, buds and twigs of woody plants during harsh winters but will also use dried herbaceous vegetation if it is not frozen. Since this species uses a wide variety of plants, food is generally not a limiting factor. (Allen 1982)

Water

The cottontail receives its water from vegetation, dew and free water (Allen 1982).

Habitat

This species is a generalist that can occupy a wide variety of habitats but any suitable habitat requires "an abundance of well-distributed escape cover interspersed within a grassland community that contains an abundance of forbs" (Allen 1982). The open herbaceous areas are used for nocturnal foraging and may be used as cover during summer. During fall and winter, this herbaceous cover is reduced so cottontails are forced to use more woody vegetation for cover and to travel greater distances to forage, which makes adequate woody cover essential for cottontails. In fact, this species has been known to select sites with suitable cover over sites with abundant food but without adequate cover. Suitable cover consists of dense cover which they can move around in but cannot be seen or attacked in (Allen 1982).

Reproduction

Nests consist of slanting holes lined with grass or fur. These nests are usually in herbaceous cover such as fallow fields with vegetation less than 20.0 cm (7.8 in) high and close to cover (Allen 1982).

Management

To provide habitat for eastern cottontail the area should be at least 4 ha (10 ac) and have open areas interspersed with woody vegetation. If food is limiting, then more than .5 acre areas should be kept in grasses and forbs by occasionally disking, plowing or burning. Also, quarter acre areas can be planted in bahia grass and clover in the spring and succulent green vegetation such as alfalfa and wheat during the winter. Cover also needs to be provided by encouraging woody vegetation and planting dense growing thorny shrubs. Allen (1982) concludes that optimum winter cover is provided when the shrub crown closure is 20 to 50% and the tree canopy closure is 25 to 50%. Also, the more percent canopy closure of persistent herbaceous vegetation, the higher quality the habitat. Artificial cover can also be provided in the form of brushpiles; however, these only last for 3 to 5 years so if this is the primary element of habitat management for this species then 1/3 to 1/4 of the brushpiles should be replaced each year. Brushpiles should be placed near the edges of the pasture or woodlot, 50 to 100 m (55 to 110 yds) apart, and should be at least 4 to 6 m (13 to 20 ft) in diameter and 1 to 2 m (3 to 7 ft) in height. Even if an area has the optimum shrub and tree cover discussed above, in order to provide suitable year round habitat it is important that this cover is well distributed with open areas. To determine if an area has optimum interspersion of habitats, the diversity index equation provided by Allen (1982) may be used (Allen 1982, Yarrow 1999).

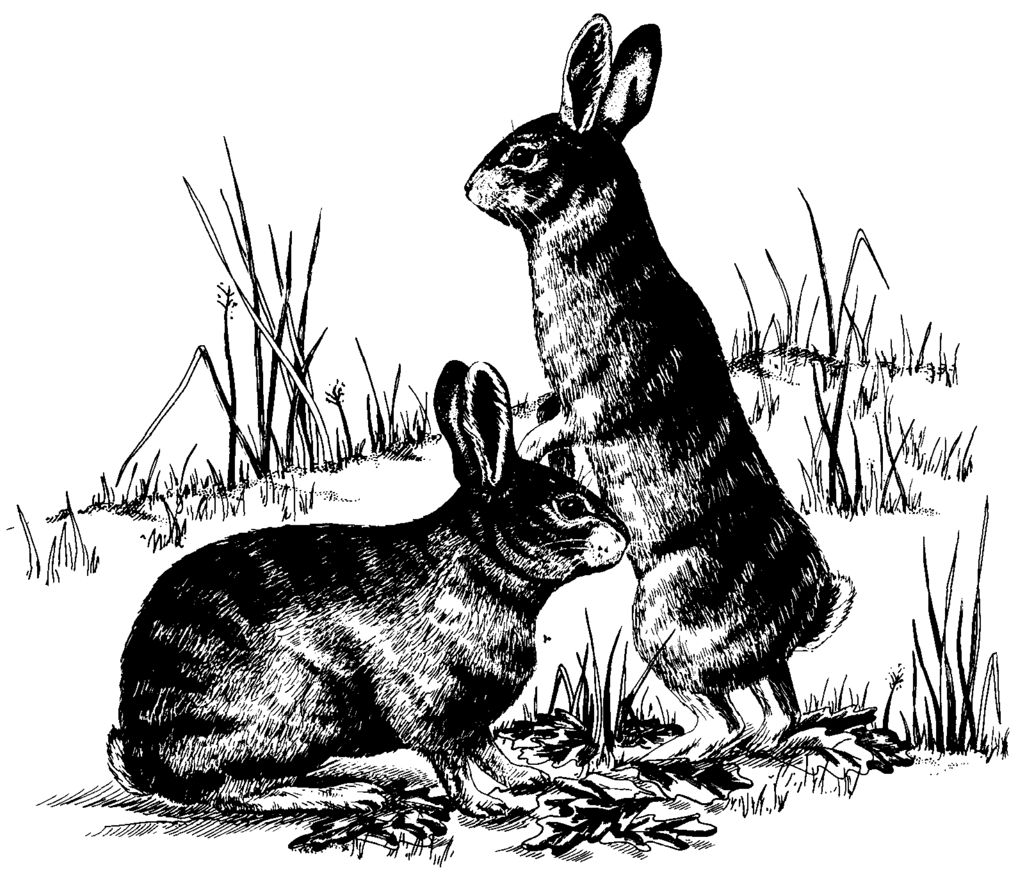
Literature Cited

Allen, A.W. 1982. Habitat Suitability Index Models: Eastern cottontail. U.S. Fish and Wildlife Service. FWS/OBS-82/10.66. 23 pp.

Yarrow, G. K. and D.T. Yarrow. 1999. Managing wildlife on private lands in Alabama and the Southeast. Alabama Wildlife Federation. Sweetwater Press, Birmingham, Alabama, USA.

FWS/OBS-82/10.66
JULY 1984

HABITAT SUITABILITY INDEX MODELS: EASTERN COTTONTAIL



Fish and Wildlife Service

S. Department of the Interior

FWS/OBS-82/10.66
July 1984

HABITAT SUITABILITY INDEX MODELS: EASTERN COTTONTAIL

by

Arthur W. Allen
Habitat Evaluation Procedures Group
Western Energy and Land Use Team
U.S. Fish and Wildlife Service
Drake Creekside Building One
2627 Redwing Road
Fort Collins, CO 80526-2899

Western Energy and Land Use Team
Division of Biological Services
Research and Development
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

This report should be cited as:

Allen, A. W. 1984. Habitat suitability index models: Eastern cottontail. U.S. Fish Wildl. Serv. FWS/OBS-82/10.66. 23 pp.

PREFACE

This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment, evaluation or management needs.

The HSI Model Section documents a habitat model and information pertinent to its application. The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The application information includes descriptions of the geographic ranges and seasonal application of the model, its current verification status, and a listing of model variables with recommended measurement techniques for each variable.

In essence, the model presented herein is a hypothesis of species-habitat relationships and not a statement of proven cause and effect relationships. Results of model performance tests, when available, are referenced. However, models that have demonstrated reliability in specific situations may prove unreliable in others. For this reason, feedback is encouraged from users of this model concerning improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning. Please send suggestions to:

Habitat Evaluation Procedures Group
Western Energy and Land Use Team
U.S. Fish and Wildlife Service
2627 Redwing Road
Ft. Collins, CO 80526-2899

CONTENTS

ACKNOWLEDGMENTS

Dr. Joseph A. Chapman, Utah State University; Mr. Kevin Morgan, Wisconsin Department of Natural Resources; Dr. Robert K. Swihart, University of Kansas, Museum of Natural History; and Dr. Richard H. Yahner, Pennsylvania State University, have provided useful and valuable critiques of an earlier draft of the eastern cottontail HSI model. The comments and suggestions of these individuals have added significantly to the quality of this HSI model, and their time and contributions are gratefully acknowledged. The cover of this document was illustrated by Jennifer Shoemaker. Word processing was provided by Carolyn Gulzow and Dora Ibarra.

EASTERN COTTONTAIL (*Sylvilagus floridanus*)

HABITAT USE INFORMATION

General

The eastern cottontail (*Sylvilagus floridanus*) is the most widely distributed cottontail in North America (Chapman et al. 1982). The species is considered to be a generalist that occupies a variety of habitats from southern Canada southward into South America (Chapman et al. 1980). The eastern cottontail's range overlaps that of six other species of cottontails (*Sylvilagus* spp.) and six species of hares (*Lepus* spp.). Eastern cottontails have been widely transplanted and are believed to be expanding their range northward, particularly in the Northeast (Chapman et al. 1982). The eastern cottontail has been successfully introduced into portions of Oregon and Washington which are outside of the species' natural range (Chapman and Morgan 1973). The eastern cottontail is primarily nocturnal and is a principal game species in the eastern United States.

Food

Cottontail food habits vary greatly depending upon the species, geographic region, and the availability of palatable plants (Chapman et al. 1982). Nearly every kind of grass, succulent herb, or flowering plant, native or introduced, will provide acceptable food for the cottontail (Sweetman 1944). The number of different plants consumed by cottontails in a given geographic area may exceed 100 species (DeCalesta 1971). Cottontails may exhibit food preferences on a local basis; however, a wide variety of vegetation is acceptable and will meet the cottontail's food requirements provided that the basic nutritional requirements of the species are met (Chapman et al. 1982). Herbaceous vegetation is typically selected during the growing season; the bark, buds, and twigs of woody vegetation are consumed during the balance of the year. The adoption of woody plants as a food source in winter results from the unattractiveness of frozen herbaceous vegetation and the reduced availability of herbaceous plants due to snow and ice coverage (Sweetman 1944). Reduced consumption of woody vegetation may occur in less severe winters and when herbaceous growth becomes available in protected sites. Dried herbaceous vegetation may comprise a substantial proportion of the cottontail's diet during periods of sparse snow cover (Korschgen 1980; Swihart and Yahner 1982-83). In southern regions with relatively mild winter climates, herbaceous vegetation alone may provide an adequate source of winter food (Swihart pers. comm.). The phenology and distribution of plant species may temporarily affect palatability and feeding preferences of cottontails, resulting in variations in local rabbit concentrations (Bigham 1966). DeCalesta (1971) provided a detailed, regionalized summary of cottontail food habits for the contiguous United States.

Due to the wide variety of vegetation used, food availability is seldom a limiting factor and typically is not the most important consideration in cottontail management (Sweetman 1944; Dusi 1952). Haugen (1942) reported that the eastern cottontail will select suitable cover over an abundant food supply if the two are not found together. The availability of food did not prevent emigration of cottontails from a Tennessee study site that lacked adequate cover (Anderson and Pelton 1976).

Water

The eastern cottontail obtains sufficient moisture from succulent vegetation, dew, and available surface water (Schwartz and Schwartz 1959).

Cover

The eastern cottontail inhabits a wide range of successional and transitional habitats (Chapman et al. 1982). No single habitat type can be categorized as preferred cover because habitat preferences of the species vary by season, latitude, geographic region, and behavorial activities. However, the essential ingredients of eastern cottontail habitat appear to be an abundance of well-distributed escape cover interspersed within a grassland community that contains an abundance of forbs. Successional seres characterized as being "old field" have been identified as preferred eastern cottontail habitat (Friley 1955; Heard 1962; Nugent 1968). Beckwith (1954) described the vegetative succession associated with abandoned farmlands in Michigan and related shifts in vegetative structure and composition to accompanying wildlife populations. Beckwith concluded that eastern cottontails were generally restricted to shrubby cover associated with field edges, or to undisturbed sites associated with successional stages dominated by grasses. All successional stages were believed to provide numerous food plants for the species; therefore, suitable cover was believed to be a more limiting characteristic of the habitats evaluated. Cottontail numbers were expected to increase as trees and shrubs became established in the mid-successional stages.

The cover requirements of the eastern cottontail can be characterized as being composed of feeding cover and resting/escape cover (Trent and Rongstad 1974). Open areas are generally used for foraging at night whereas dense, heavy cover is typically selected for shelter during the day (Chapman et al. 1982). During summer the two basic cover requirements are generally provided by the same vegetation (Trent and Rongstad 1974). During late fall and winter both cover requirements become more restrictive due to the desiccation of herbaceous vegetation and the loss of foliage from woody vegetation. The reduction of available herbaceous cover forces cottontails to forage in less secure cover and travel greater distances during foraging activities. Similar conclusions were drawn by Janes (1959) who recorded average summer foraging distances for eastern cottontails of 53.3 m (175.0 ft) and winter foraging distances of 99 m (325 ft). Chapman et al. (1982) concluded that it is probable that eastern cottontails use woody cover considerably more during the winter months, particularly where dense herbaceous vegetation provides adequate summer cover. Other studies also have reported increased reliance upon woody vegetation by eastern cottontails during the winter, presumably in response to decreased herbaceous cover (Kline and Hendrickson 1954; Bigham 1970). Winter forms (resting sites) in Minnesota were closer to overstory tree boles, surrounded by a greater number of woody stems, and associated with larger sapling-sized trees, than were randomly located points (Swihart and Yahner 1982a). Eastern cottontails in Illinois increased their use of woody vegetation as snow depth increased (Hansen et al. 1969). Trent and Rongstad (1974) recorded increased cottontail use of retreats (e.g., holes, woodpiles, and junkpiles) as vegetative cover decreased and snow depths increased. Areas dominated by dense, robust, herbaceous vegetation may provide adequate winter food and cover in southern portions of the eastern cottontail's range where extreme snowfall does not reduce vegetative cover (Swihart pers. comm.).

The importance of woody vegetation to survival and abundance of the eastern cottontail cannot be overemphasized (Swihart 1981). Trees and shrubs provide the eastern cottontail with food, shelter, and escape cover, and may be a limiting factor in defining the quality of eastern cottontail habitat throughout much of the rabbit's range. Trent and Rongstad (1974) also related cottontail survival to the abundance and distribution of suitable cover. Eastern cottontail concentration areas in Tennessee were characterized as being comprised of thick vegetative cover of poor penetrability in close proximity to other areas of sparse vegetative cover (Anderson and Pelton 1976). Preferred habitats were areas of dense, tangled cover, through which the rabbits were able to move in a variety of directions without being detected, or areas where rabbits were visible for only short periods of time as they moved across small openings. Ideally, eastern cottontail habitat is composed of areas with grassland; hedgerows; and low, dense, woody vegetation that provide escape cover and refuge sites (Smith 1950). The presence and abundance of woody vegetation was reported to significantly influence the use of habitat by cottontails in Minnesota (Swihart and Yahner 1982b). Eastern cottontails were more likely to establish residence within shelterbelts than in other nearby habitat types. Eastern cottontails captured in fencerow/roadside habitats, which typically contained no woody vegetation or woody vegetation of low quality, were generally transients or used the habitat on a temporary basis in conjunction with a contiguous shelterbelt. Extensive use of hedgerows by eastern cottontails in Maryland was attributed to greater abundance of horizontal cover, 0 to 0.5 m (0 to 1.6 ft) in height, than was present in other nearby cover types (Morgan and Gates 1983). The relatively dense woody cover near the ground surface within hedgerows provided numerous refuge sites for cottontails. Bigham (1970) recorded concentrated establishment of cottontail forms in Oklahoma where the overhead canopy cover of woody vegetation was ≥ 50% with little regard for stem density. Most escape sites were located where overhead canopy was ≥ 70% with low stem density. The removal of brushy fencerows was a major factor in the deterioration of cottontail habitat in Oregon (Verts and Carraway 1981). Tall, dense clump grasses [e.g., switchgrass (Panicum virgatum)] that stand well under winter snow provide winter cover for eastern cottontails, and may, to some degree, reduce the need for woody escape cover (Chapman et al. 1982).

Strip vegetation resulting from plantings, or from the fragmentation of larger blocks of habitat, is an important component of eastern cottontail habitat (Morgan and Gates 1983). Cottontails inhabiting shelterbelts in Minnesota were reported to be in better physical condition, and less prone to precipitous population declines, than were rabbits inhabiting wooded grassland or fencerow/roadside habitats (Swihart 1981). Shelterbelts supported higher winter densities of eastern cottontails than did wooded grassland habitats. Because of their linear design, shelterbelts exhibit a high perimeter to area ratio. Eberhardt et al. (1963) suggested that cottontail home ranges are typically oblong rather than circular; hence, shelterbelts and cottontail home ranges complement each other. Fencerows reduce the influence of barriers created by open fields and provide important travel corridors in farmland habitats (Bruna 1952 cited by Chapman et al. 1982; Wegner and Merriam 1979). Concentrated activity of small mammals in habitat corridors provided by fence-rows or shelterbelts may relieve the isolating effect of farmland surrounding wooded habitats. Edwards et al. (1981) concluded that a major difficulty in cottontail management was that islands of suitable habitat are becoming both smaller and increasingly isolated. As habitat isolation increases, eastern cottontail abundance decreases because of an imbalance between emigration and immigration. Chapman (1971) reported that brush rabbits (S. bachmani) did not permanently inhabit clumps of brambles less than approximately 465 m^2 (5,000 ft^2) in area. Areas of cover of this size, or smaller, were used only if they were in proximity to larger units of cover.

Although the presence of cultivated land may increase seasonal food availability for the eastern cottontail, croplands generally eliminate the more permanent sources of food and cover typically available on uncropped lands (Friley 1955). Trent and Rongstad (1974) recorded less than 8% of eastern cottontail daytime resting sites within agricultural land. It appeared that only agricultural land within 91.4 m (300.0 ft) of a woodlot was used by the cottontail population inhabiting it. The continuous disturbance of soil and vegetation in heavily grazed areas results in low use by cottontails (Friley 1955).

Land use must be regarded as the most influential factor affecting long term cottontail abundance (Edwards et al. 1981). Although population cycles are possible, any periodicity in eastern cottontail abundance over the past 20 to 25 years has been of minor importance when compared to the influence of changing land use patterns (Chapman et al. 1982). Throughout much of their range, eastern cottontail abundance has declined due to: reductions in grass-lands, stream and river bottom forests, and woodlots; the plowing or "improve-ment" of weedy and brushy pastures; and overgrazing. Edwards et al. (1981) concluded that the greatest declines in cottontail abundance in Illinois have occurred where agricultural land use has been most intense. A comparison of eastern cottontail population indices between 1956 and 1978 indicated that declines in cottontail abundance probably exceeded 70% on a statewide basis and 90 to 95% in intensively farmed portions of that State. Less severe reductions in cottontail abundance were recorded in areas with the best inter-spersion of woody cover, pasture, and grassland. Reduced eastern cottontail abundance appeared to be associated with a decrease in the number of individual farms and diminished acreage devoted to the production of hay and oats. Comparing eastern cottontail abundance in Illinois between 1939 and 1974, Vance (1976) concluded that the major reduction in rabbit abundance could be attributed to the intensification of cash-grain farming. The emphasis on grain production has resulted in an increased average field size, a drastic reduction of grass-dominated cover types, and a reduced quantity and quality of fencerows. The loss of brushy fencerows was believed to be particularly detrimental to eastern cottontail populations. Brushy fencerows were reduced by 84% within the study area, and remaining fencerows were of poor quality due to their narrowness and sparse vegetative cover. Swihart and Yahner (1982b) concluded that nonwooded habitats with little artificial cover are unsuitable for permanent occupancy by eastern cottontails in a modern agro-ecosystem. Fencerows with little woody vegetation and roadside vegetation are generally unfit for year-round use by cottontails in intensively farmed areas. Long term reductions in eastern cottontail populations can be expected to continue unless there is a decline in intensive agricultural land use (Chapman et al. 1982).

Reproduction

Eastern cottontails typically construct nests in slanting holes that contain an outer lining of grass, or herbaceous stems, with an inner lining of fur (Chapman et al. 1982). Most cottontail nests are located in grass cover. Eastern cottontails in Michigan exhibited a spring movement from woody winter cover to upland herbaceous cover for the establishment of nest sites (Friley 1955). Fallow fields and hayfields were believed to be the most important nest cover. The use of croplands in Wisconsin by eastern cottontails for the establishment of nest sites was minimal (Trent and Rongstad 1974). Early nests of eastern cottontails are generally situated in grassy vegetation less than 15.0 cm (5.9 inches) tall (Chapman 1982). Nest sites located in an Iowa study were within 64.2 m (70.0 yd) of brush cover in herbaceous vegetation greater than 10.2 cm (4.0 inches) in height (Hendrickson 1940). Cottontail summer nests in hayfields were typically in vegetation less than 20.0 cm (7.8 inches) in height. Eastern cottontail nests located in a Maryland study were located near dense cover and were constructed against tree stumps or surrounded by vegetation, usually ferns (Filicinae) (Bruch and Chapman 1983).

Interspersion

Factors that affect the size of the eastern cottontail's home range include: (1) age and sex of the individual; (2) type, arrangement, and stability of the habitat; (3) season; (4) weather patterns; (5) population density; and (6) intraspecific and interspecific competition (Chapman et al. 1982). The home ranges of different ages and sexes overlap during most of the year, particularly during the fall and winter when cottontails tend to concentrate in areas providing the best combination of food and cover. Eastern cottontail home range size during late fall, winter, and early spring is a function of food distribution, regardless of sex or age (Trent and Rongstad 1974). As cover abundance becomes reduced in late fall and winter, eastern cottontail home ranges tend to become larger and are focused around some type of dense escape cover (Janes 1959; Chapman et al. 1982). The eastern cottontail's home range is roughly circular in uniform habitats and is used most near its center and least toward the periphery (Janes 1959). Eastern cottontails typically inhabit one home range for the duration of their life, although minor shifts in home range use in response to vegetation changes and weather are common. Anderson and Pelton (1976) reported that eastern cottontails that did shift their home ranges were not observed to return to their original home range. Temporary home range departures were recorded after the onset of the breeding season. Unless a sudden reduction of cover occurred, cottontails remained within their home range. Harvesting of crops did result in evacuation of home ranges. Swihart and Yahner (1982b) also recorded abandonment of home ranges as a result of crop harvest. Emigration from home ranges within croplands resulted in autumn and winter concentrations of eastern cottontails within nearby wooded habitats.

Local populations of eastern cottontails may reach a density of 20 rabbits/ha (8/acre) although densities are normally lower (Chapman et al. 1982). The average winter home range size for male and female eastern cottontails in Tennessee was 2.8 ha (6.9 acres) and 2.2 ha (5.4 acres), respectively (Anderson and Pelton 1976). Male cottontails in Wisconsin had an average spring home range size of 2.8 ha (6.9 acres), and an average early summer home range of 4.0 ha (9.8 acres) (Trent and Rongstad 1974). Adult female eastern cottontails had an average spring home range of 1.7 ha (4.2 acres) and an average early summer home range of 0.8 ha (1.9 acres). Eastern cottontails in Kansas were believed to maintain an average home range of 3.4 ha (8.34 acres) (Janes 1959). The home ranges of male cottontails averaged 0.5 ha (1.16 acres) larger than those of females. Daily foraging activities were typically restricted to 10 to 20% of the overall home range.

Special Considerations

Habitat diversity and interspersion are the key elements in eastern cottontail management (Chapman et al. 1982). Interspersion of fields and woody vegetation along with creation of edge by breaking up large, continuous units of monotypic habitat have proven beneficial in habitat management for the species.

A variety of management techniques have been used to create or improve eastern cottontail habitat. Encouraging the growth of woody vegetation and developing artificial cover enhance cottontail habitat (Swihart 1981). The establishment of brushpiles is an effective means to increase an area's potential to support cottontails (Madson 1959, cited by Chapman et al. 1982; Pils et al. 1981; Swihart 1981). Brushpiles should be at least 4 to 6 m (13 to 20 ft) in diameter and 1 to 2 m (3 to 7 ft) in height (Chapman et al. 1982). Brushpiles should be situated near the edges of woodlots, fields, pastures, or other sites where vegetation provides food and limited additional cover. Brushpiles should be distributed at distances of 50 to 100 m (55 to 110 yds) whenever practical. However, the creation of brushpiles is considered only a temporary solution and their establishment should not be considered a substitute for more permanent vegetative cover. Most brushpiles lose their effectiveness for providing adequate cottontail cover within 3 to 5 years after their establishment. If the creation of brushpiles is the primary element of a habitat management program for cottontails, 1/3 to 1/4 of the brushpiles should be replaced annually. Thorny shrubs that maintain a low, dense, clump growth form should be selected when shrub planting is considered as a management option (Chapman et al. 1982). Similarly, Morgan and Gates (1983) recommended that shrubs with a growth form similar to multiflora rose (Rosa multiflora) be selected when establishing escape cover for the eastern cottontail. The establishment of conifers, particularly spruce (Picea spp.) and shrubs (e.g., Lonicera spp., Viburnum spp., and Prunus spp.) in shelterbelts increases their suitability as eastern cottontail cover (Swihart 1981). However, coniferous species may not provide an adequate winter food source for the cottontail (Swihart and Yahner 1983; Swihart pers. comm.). Podoll (1979) provided a summary of vegetation useful as eastern cottontail food and cover and recommended techniques for establishment of structural diversity for the enhancement of shelterbelts as cottontail habitat. Regardless of species composition, strip habitat (e.g., windbreaks and shelterbelts) should consist of dense, woody vegetation ≥ 1 to 2 m (1 to 2 yds) in height and at least 5.0 m (5.4 yds) wide to provide ideal cottontail cover (Morgan pers. comm.). Swihart and Yahner (1983) provide guidance for shelterbelt planting stock in relation to species susceptibility to browsing damage by eastern cottontails and white-tailed jackrabbits (Lepus townsendii). Lord (1963) concluded that extremely dense or high grass can restrict use of an area by eastern cottontails. The mowing of such fields increased their use by cottontails. Hedgerows with mowed grass borders had greater eastern cottontail use than any other cover type surveyed in a Maryland study (Morgan and Gates 1983). Swihart and Yahner (1982-1983) postulated that the cessation of mowing between shelterbelt rows may allow the establishment of preferred cottontail winter forage [e.g., gooseberry (Ribes spp.) and blackcap raspberry (Rubus occidentalis)] and reduce potential damage to planted trees resulting from winter browsing. Limited grazing can be effectively used in cottontail management (Ellis et al. 1969). Pils et al. (1981) provided a summary of literature related to cottontail habitat management throughout the United States.

The eastern cottontail uses vegetative types associated with early and mid-successional stages; thus, natural succession should be taken into account in any management program that focuses on maintaining or enhancing eastern cottontail habitat (Chapman et al. 1982). Ellis et al. (1969) concluded that habitat management for upland game species, including cottontails, should be based upon the manipulation of natural succession. Management goals should be oriented toward the maintenance of appropriate successional patterns through periodic disturbance rather than the actual creation of habitat (e.g., planting to provide food and cover). Sharecropping, prescribed burning, and combinations of the two activities were recommended as being ecologically sound and economically feasible techniques in the management of vegetative succession.

Friley (1955) recommended that eastern cottontail management efforts be directed toward securing a cover pattern that provides nesting and escape cover within an area not exceeding 12 ha (30 acres). A ratio of 8 ha (20 acres) of cover to 40 ha (100 acres) of cropland was believed to be sufficient to support high numbers of eastern cottontails in Tennessee (Anderson and Pelton 1976). Fall densities of eastern cottontails approaching 2 to 3/ha (2 to 3/2.5 acres) is a realistic management goal on managed areas of 500 ha (1,236 acres) or larger, where forested cover types do not exceed 25% of the total area (Chapman et al. 1982).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model has been developed for application throughout the eastern cottontail's range (Fig. 1).

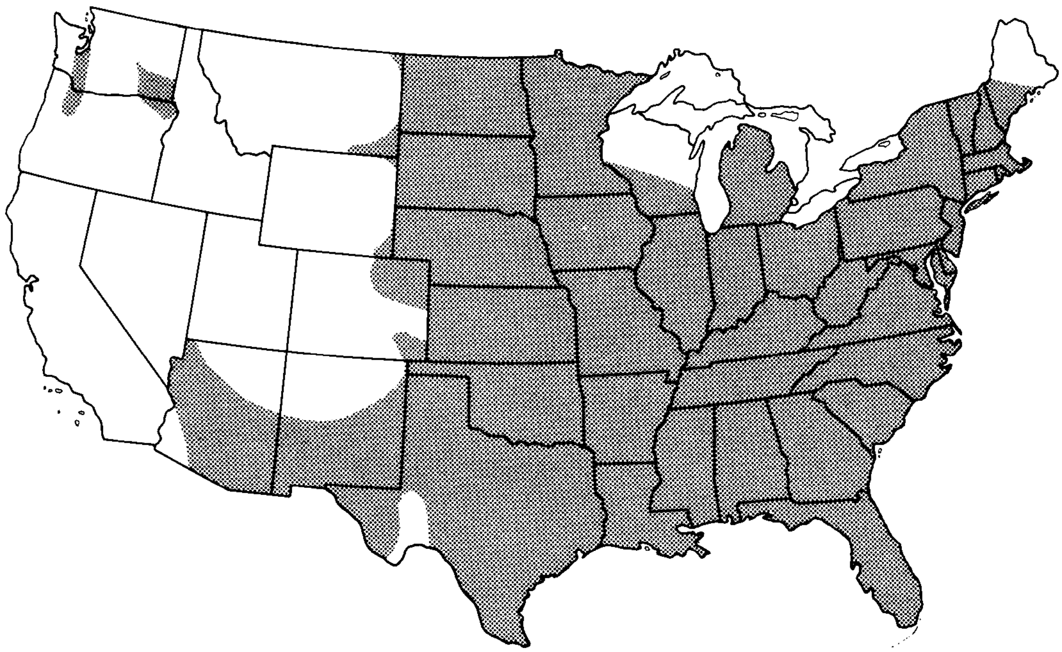


Figure 1. Approximate distribution of the eastern cottontail in the contiguous United States (modified from Chapman et al. 1982).

Season. This model has been developed to evaluate the potential quality of winter habitat for the eastern cottontail. Cover and food requirements for the species are more restrictive during winter than during the balance of the year. This model is based on the assumption that year-round eastern cottontail habitat will be present if winter cover and food of sufficient quality are available. As a result of less severe winter conditions, the eastern cottontail's dependence upon adequate winter cover and food may not be as pronounced in the more southern portions of the species' range.

Cover types. This model has been developed to evaluate potential habitat quality in the following cover types (terminology follows that of U.S. Fish and Wildlife Service 1981): Cropland (C); Pasture/Hayland (P/H); Evergreen Forest (EF); Deciduous Forest (DF); Evergreen Shrubland (ES); Deciduous Shrubland (DS); Evergreen Shrub Savanna (ESS); Deciduous Shrub Savanna (DSS); Grassland (G); and Forbland (F).

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before an area will be occupied by a species. Specific information on the minimum habitat area required by the eastern cottontail was not located in the literature. However, the majority of mean home range sizes reported in the literature are less than 4 ha (10 acres) in area. Based on this information, it is assumed that a minimum of 4 ha (10 acres) of potential habitat is required to support a population of eastern cottontails.

Verification level. This HSI model provides habitat information useful for impact assessment and habitat management. The model is a hypothesis of species-habitat relationships and does not reflect proven cause and effect relationships. An earlier draft of this model was reviewed by Dr. Joseph A. Chapman, Utah State University; Mr. Kevin Morgan, Wisconsin Department of Natural Resources; Dr. Robert K. Swihart, University of Kansas; and Dr. Richard H. Yahner, Pennsylvania State University. Improvements and modifications suggested by these persons have been incorporated into this model.

Model Description

Overview. The eastern cottontail uses a diversity of herbaceous and woody vegetation for food and cover on an annual basis. The species is adaptable and can successfully inhabit a variety of habitat types if sufficient food and cover are provided. In regions with severe winter weather, the eastern cottontail depends upon woody vegetation as a source of winter food, escape cover, and thermal cover. It is assumed that winter food and cover provided by woody vegetation are interdependent characteristics of the eastern cottontail's habitat. Areas providing an abundant supply of woody vegetation well interspersed with areas dominated by herbaceous vegetation and/or agricultural lands are assumed to characterize potentially optimum year-round eastern cottontail habitat.

The following sections provide documentation of the logic and assumptions used to translate habitat information for the eastern cottontail to the variables and equations used in the HSI model. Specifically, these sections cover: (1) identification of variables; (2) definition and justification of the suitability levels of each variable; and (3) description of the assumed relationships between variables.

Winter cover/food component. The eastern cottontail subsists entirely upon herbaceous vegetation during the spring, summer, and early fall. During these seasons, herbaceous vegetation of sufficient height and density also provides shelter and escape cover. Row, grain, and hay crops provide additional cover and food on a seasonal or temporary basis. With the onset of winter, and the decreased availability and quality of herbaceous vegetation, the eastern cottontail becomes almost entirely dependent upon the buds, stems, twigs, and bark of woody vegetation as a food source. In response to the reduction of available herbaceous vegetation, shrubs and trees also become the eastern cottontail's major source of winter thermal and escape cover. This model is based on the assumption that year-round habitat quality for the eastern cottontail is defined by the quality and distribution of winter habitat. It is assumed that adequate amounts of spring/summer food and cover (generally provided by herbaceous plants and/or agricultural crops) will never be more limiting than a source of suitable winter food and cover.

The abundance and distribution of shrubs, trees, and persistent herbaceous vegetation are assumed to be indicative of the potential quality of winter habitat for the eastern cottontail. This model does not take into account the locally important potential cover that may be provided by animal burrows, man-made features or other non-vegetative habitat features. It is assumed that sufficient amounts of winter cover must be present within, or adjacent to, a cover type in order for it to provide year-round eastern cottontail habitat. Cover types that do not contain or adjoin areas supporting woody vegetation may provide suitable spring/summer habitat. However, such areas will not provide suitable winter habitat and are therefore assumed to be characteristic of unsuitable year-round habitat for the species. Herbaceous dominated cover types adjacent to woody cover may be used to a limited degree by the eastern cottontail during the winter months. Linear woody cover types (e.g., fencerows, windbreaks, narrow riparian woodlands) are assumed to be used in their entirety by the eastern cottontail throughout the year. Large units of woody habitat (e.g., woodlots, forests) are assumed to receive their greatest amount of use where these habitats form an interface with croplands or other herbaceous dominated cover types. During the fall and winter, eastern cottontails will shift their use of habitat into the more secure cover provided by woodlands in response to disturbance from crop harvesting and decreased abundance of herbaceous vegetation. It is assumed that the interior portions of woodlots or forested cover types will be used to a greater extent by eastern cottontails during the winter months than during the spring or summer when nonwooded areas provide adequate food and cover.

Winter habitat quality for the eastern cottontail is assumed to be a function of habitat structure that includes: (1) percent shrub crown closure; (2) percent tree canopy closure; and, to a limited degree, (3) the percent canopy closure of persistent herbaceous vegetation. The assumed relationships between vegetative density and suitability index values for eastern cottontail cover/food habitat quality are presented in Figure 2.

Figure 2a presents the assumed relationship between shrub density [woody vegetation $\leq$ 5 m (16.5 ft) tall] and a winter cover/food index value. Optimum conditions are assumed to exist when shrub crown closure ranges between 20 to 50%. Shrub density below 20% is assumed to be indicative of lower habitat quality due to a minimum amount of available cover and winter food. Shrub density in excess of 50% is assumed to reflect slightly lower habitat quality due to a reduction in openings and the potential availability of herbaceous growth during green-up periods. Complete shrub canopy closure is assumed to indicate habitat of lower potential, not unsuitable habitat.

Figure 2b shows the assumed relationship between tree canopy closure and a winter cover/food index value for the eastern cottontail. The presence of trees is assumed to enhance an area's potential as eastern cottontail winter habitat. However, the presence of trees without a shrub understory is assumed to reflect eastern cottontail winter habitat of low quality. Dense forest stands, or woodlots (> 50% tree canopy closure), are assumed to inhibit the growth of intolerant shrubs resulting in less suitable winter habitat for the

Fig. 2a

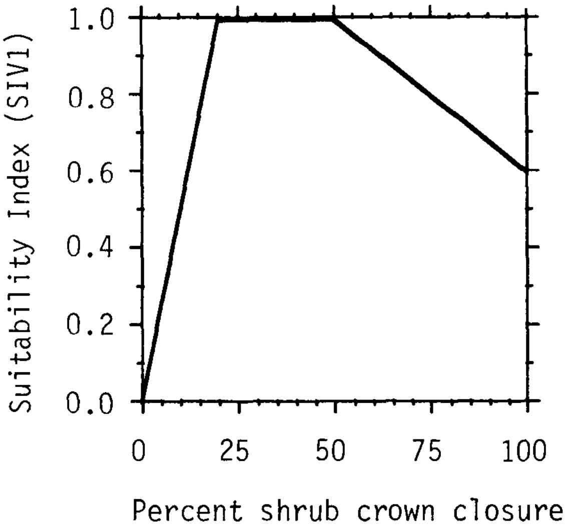


Fig. 2b

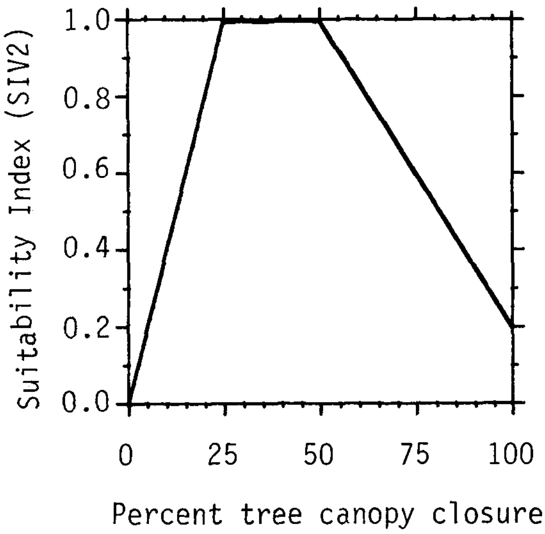


Fig. 2c

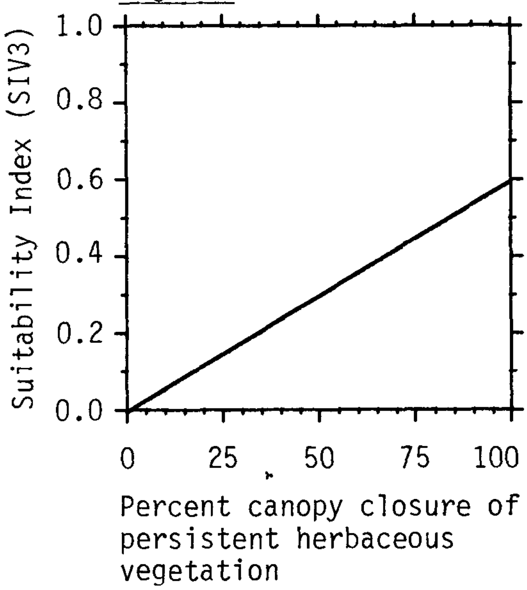


Figure 2. The relationships between habitat variables used to calculate the winter cover/food value for the eastern cottontail and the suitability indices for the variables.

species. Optimum tree density is assumed to range from 25 to 50% tree canopy closure. Tree canopy closure below 25% is assumed to reflect lower habitat quality due to reduced food and cover availability.

The relationship of nonwoody vegetation that normally remains standing after the growing season (i.e., persistent) to a suitability index value for eastern cottontail winter habitat quality is presented in Figure 2c, percent canopy closure of persistent herbaceous vegetation. In northern regions, the presence of persistent herbaceous growth may increase an area's ability to provide adequate winter habitat. However, even extremely dense, herbaceous vegetation is assumed to provide habitat of relatively low potential if woody vegetation is sparse or absent. Regions with little to no persistent snow cover may permit dense robust stands of herbaceous vegetation to play a greater role in meeting the eastern cottontail's winter cover and food requirements. Therefore, users of this model in southern portions of the cottontail's range may wish to assign greater weight to the herbaceous component of this model.

The index values calculated using the curves presented in Figure 2 are combined in Equation 1 to determine a winter cover/food index (WCFI) for the eastern cottontail in specific cover types.

$$\text{WCFI} = \text{maximum value of } \frac{(4(\text{SIV1}) + \text{SIV2})}{5} + \text{SIV3} \quad \text{or} \quad 1.0 \tag{1}$$

As presented in the above equation, the density of shrubs, trees, and persistent herbaceous vegetation is assumed to be additive in the definition of winter habitat quality for the eastern cottontail. Cover types, with all three vegetative features present at optimum densities, have greater potential for meeting the eastern cottontail's winter habitat requirements than would a site with only one or two of the vegetative features present. Shrub density (SIV1) is assumed to be the most influential component in defining eastern cottontail winter habitat quality and is weighted in the equation to reflect this assumption. The percent tree canopy closure (SIV2) on any area is assumed to have only one-fourth the potential of the percent shrub canopy closure for providing suitable winter cover/food conditions. The presence of persistent herbaceous vegetation (SIV3) in association with shrubs and trees is assumed to increase an area's ability to provide adequate winter cover/food for the eastern cottontail. The structure of equation 1 permits an optimum value to be obtained in the complete absence of persistent herbaceous vegetation if sufficient amounts of woody vegetation are present. The presence of herbaceous vegetation enhances an area's winter cover/food potential if suboptimum densities of woody vegetation are present. Equation 1 may result in a value that exceeds 1.0 if robust herbaceous vegetation is present in an area that supports tree and shrub densities that are in the assumed optimum ranges. In such situations, the WCFI value should be reduced to 1.0. Cover types supporting only persistent herbaceous vegetation are assumed to have relatively low value as eastern cottontail winter habitat in the more northerly portions of the species' range.

Interspersion component. The major assumption of this model is that woody vegetation, particularly shrubs, must be present in order to provide high quality year-round habitat for the eastern cottontail. Although the total amount of woody vegetation present within a study area may be within the assumed optimum range to meet the eastern cottontail's winter cover and food requirements, the juxtaposition of woody vegetation and herbaceous dominated cover types may have a significant effect on an area's potential as year-round habitat. For example, even though only a small proportion of a study area may provide suitable winter cover/food, the area may still be ranked as relatively high in value if the existing cover is well distributed throughout the entire study area. Conversely, the overall value of an area may be relatively low as year-round eastern cottontail habitat, if woody vegetation is concentrated in one homogeneous block, even when the total percentage of the area with woody cover represents assumed optimum conditions.

Application of this model requires that a winter cover/food value be determined for each cover type within the evaluation area. The HSI for the eastern cottontail in evaluation areas composed of one homogeneous cover type is equivalent to the winter cover/food index (equation 1). In study areas composed of two or more cover types, an overall winter cover/food value can be calculated by multiplying the winter cover/food index (equation 1) for each cover type by the cover type's proportion (%) of the entire study area and summing these products.

The following steps should be taken to determine a winter cover/food index value for each cover type within the evaluation area.

1. Stratify the evaluation area into cover types.

2. Divide the area of each cover type by the total area of the evaluation area to determine the relative area (%) of each cover type.

3. Determine the winter cover/food index (WCFI) for each cover type through the use of equation 1.

4. Multiply the relative area of each cover type (%) (step 2) by its WCFI value (step 3).

5. Sum the products calculated in step 4 for all cover types to obtain a weighted WCFI value.

The steps outlined above are expressed by equation 2:

$$\text{WCFI weighted by area} = \frac{\sum_{i=1}^{n} \text{WCFI}_i A_i}{\Sigma A_i} \qquad (2)$$

where n = number of cover types

$WCFI_i$ = WCFI of individual cover type

A_i = area of cover type i

An interspersion value for an evaluation area may be determined by identifying those cover types that provide a WCFI value. If all cover types provide winter cover/food, the HSI is equal to the value determined through the application of equation 2. If one or more cover types have a winter cover/food index of 0.0, the degree of interspersion between cover types providing winter cover/food to those that do not provide the required resources must be calculated to determine a final HSI value.

The interspersion value may be calculated by measuring the length of perimeter of all cover types in the evaluation area that have a WCFI value > 0.0. Multi-row shelterbelts provide better eastern cottontail habitat than do single-row shelterbelts. Single-row shelterbelts should be considered as being linear habitat features; therefore, only their length should be included in calculation of the diversity index. In contrast, multi-row shelterbelts should have their entire perimeter included in the calculation. The perimeter of cover types that have a 0.0 WCFI value should not be included in the calculation.

The interface, or edge, between two cover types that each have a WCFI value > 0.0 should be counted only once in order to prevent double counting. Example 4 in Figure 4 illustrates this concept. The interspersion diversity index for a study area is calculated through using equation 3.

$$DI = \frac{TPWC}{2\sqrt{A\pi}} \qquad (3)$$

where DI = diversity index

TPWC = the total perimeter of cover types containing winter cover/food (e.g., WCFI > 0.0) in study area

A = total area of study area

The diversity index value calculated using equation 3 is converted to a suitability index value by entering the diversity index value into the curve presented in Figure 3.

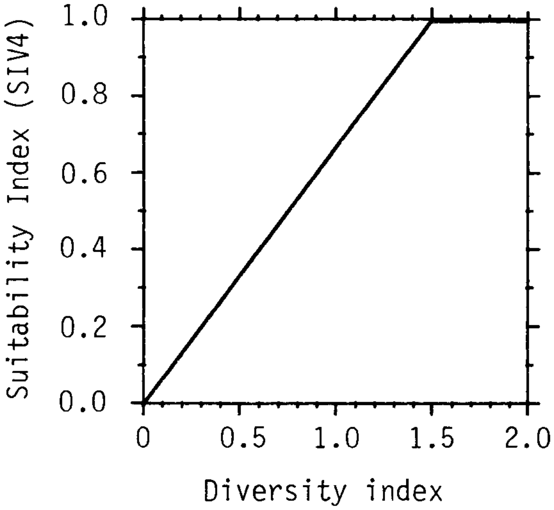
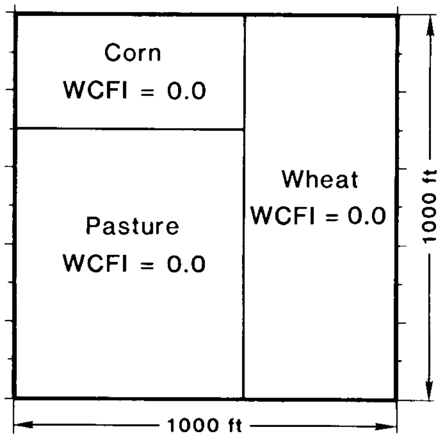


Figure 3. The relationship between the diversity index value calculated using equation 3 and a suitability index value.

The curve presented in Figure 3 was developed based on the assumption that areas composed of cover types containing no woody vegetation or dense, robust herbaceous vegetation are of almost no value as year-round eastern cottontail habitat regardless of the number and interspersion of cover types present. Equation 3 is provided to calculate a index value to estimate the degree of interspersion of cover types within an evaluation area. The diversity index value calculated using equation 3 will be of low value in areas that are comprised of few, large cover types. Conversely, areas characterized by a relatively large number of distinct cover types will have relatively large diversity index values. The diversity index value (equation 3) must be converted to a suitability index (SI) value using the curve (SIV4) presented in Figure 3. A diversity index value $\geq$ 1.5 is assumed to represent an optimum SI value. However, the precise value that represents optimum interspersion of cover types for the eastern cottontail is unknown. The optimum value of 1.5 for the diversity index was selected based on sample data sets similar to those presented in Figure 4. Users of this model may wish to adjust the optimum diversity index value based on their experience and knowledge of local optimum eastern cottontail habitat. Figure 4 illustrates example calculations of the diversity index for cover types providing winter cover/food for the eastern cottontail.

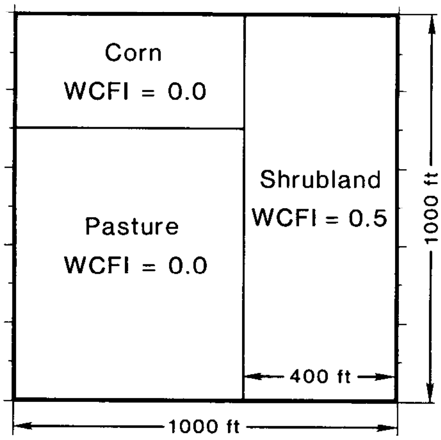
Example 1

Study area is composed entirely of cropland and pasture. Although different vegetative types are present within the study area, woody vegetation is entirely absent resulting in a diversity index of 0.0.



Example 2

Shrubland, providing potential year-round habitat, is bordered by pasture and corn. The entire shrubland edge is used to calculate the diversity index. The interface of corn and pasture is not included in the calculation since neither cover type provides winter cover or food.



$A = 1{,}000{,}000 \text{ ft}^2$

$TP = 2{,}800 \text{ ft}$

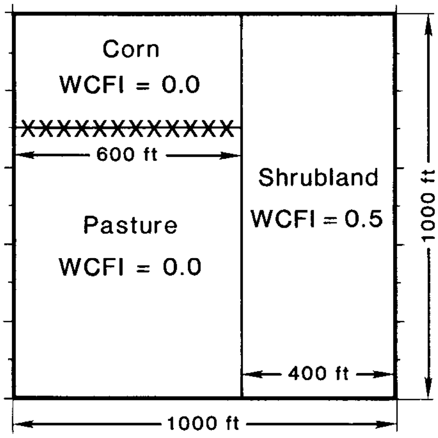
$$DI = \frac{2{,}800 \text{ ft}}{2\sqrt{1{,}000{,}000 \text{ ft } (3.1416)}}$$

$DI = 0.78$

Figure 4. Example applications of diversity index used for the calculation of the interspersion of cover types that provide potential winter cover and food for the eastern cottontail.

Example 3

Vegetative characteristics are the same as example 2 except that a shrubby fencerow now separates the pasture from the corn field resulting in an increased diversity index value.



$A = 1{,}000{,}000\ ft^2$

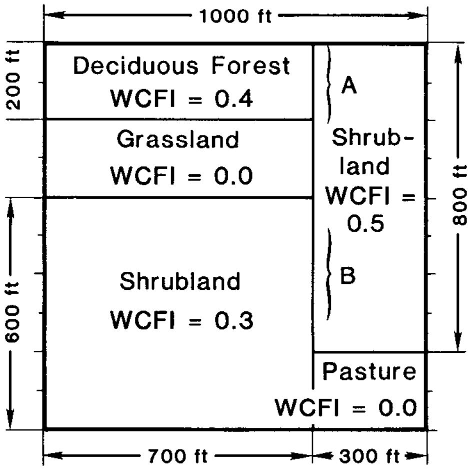
$TP = 3{,}400\ ft$

$$DI = \frac{3{,}400\ ft}{2\sqrt{1{,}000{,}000\ ft\ (3.1416)}}$$

$DI = 0.95$

Example 4

Area 4 is composed of a block of deciduous forest, two shrubland types, grassland, and pasture. The grassland and pasture cover types do not contain woody vegetation and have HSI values of 0.0. The deciduous forest and shrubland cover types have HSI values > 0.0, therefore the sum of the perimeters of each cover type is used to determine the diversity index for the study area. The values for the edge between the deciduous forest and shrubland (line A) and two shrubland types (line B) should be used in the calculation only once in order to prevent double counting resulting in an inaccurate index value. For example, if the deciduous forest perimeter is tallied, line A should be excluded from the tally of the adjacent shrubland perimeter.



$A = 1{,}000{,}000\ ft$

$TP = 6{,}000\ ft$

$$DI = \frac{6{,}000\ ft}{2\sqrt{1{,}000{,}000\ ft\ (3.1416)}}$$

$DI = 1.69$

Figure 4. (concluded).

Model Relationships

HSI determination. The calculation of a Habitat Suitability Index for the eastern cottontail considers the values obtained for the weighted winter cover/food index value (equation 1) and the diversity suitability index value derived from Figure 3. The relationship is expressed by a geometric mean of the indices for the two variables, as in equation 4.

$$HSI = (WCFI \times SIV4)^{1/2} \tag{4}$$

The availability of suitable amounts of winter cover and food and the distribution of those resources are assumed to be of equal value in defining habitat potential for the species.

Summary of model variables. Four habitat variables are used in this model to evaluate a winter cover/food value for the eastern cottontail. The relationships between habitat variables, the winter cover/food life requisite value, cover types, and an HSI value are summarized in Figure 5.

Habitat variable	Life requisite	Cover types	
Percent shrub crown closure Percent tree canopy closure Percent canopy closure of persistent herbaceous vegetation Diversity Index	Winter cover/ food	Cropland Pasture/hayland Evergreen forest Deciduous forest Evergreen shrubland Deciduous shrubland Evergreen shrub savanna Deciduous shrub savanna Grassland Forbland	HSI

Figure 5. Relationships of habitat variables, life requisites, and cover types to an HSI for the eastern cottontail.

Application of the Model

Values for habitat variables used to evaluate the winter cover/food value for the eastern cottontail can be estimated from aerial photographs. More precise measures of variable values may be obtained by collecting field data using transects and/or quadrats. Figure 6 provides a definition of each variable and suggested field measurement techniques (Hays et al. 1981).

Variable (definition)		Cover types	Suggested techique
V_1	Percent shrub crown closure [the percent of the ground surface that is shaded by a vertical projection of the canopies of woody vegetation < 5.0 m (16.5 ft) in height].	P/H,EF,DF,ES, DS,ESS,DSS,G,F	Remote sensing, line intercept
V_2	Percent tree canopy closure [the percent of the ground surface that is shaded by a vertical projection of the canopies of woody vegetation ≥ 5.0 m (16.5 ft) in height].	P/H,EF,DF,ES, DS,ESS,DSS,G,F	Remote sensing, line intercept
V_3	Percent canopy closure of persistent herbaceous vegetation (the percent of the ground surface that is shaded by a vertical projection of all non-woody vegetation that may be expected to remain standing after the growing season).	P/H,EF,DF,ES, DS,ESS,DSS,G,F	Line intercept, quadrat

Figure 6. Definitions of variables and suggested measurement techniques.

Variable (definition)	Cover types	Suggested techique
V_4 Diversity Index (a measure of the amount of cover type edge within the study site. The ratio of cover type edge to total area is compared to that for a circle having the same area as the study site, using the following formula: $$DI = \frac{TPWC}{2\sqrt{A\pi}}$$ where DI = diversity index; TPWC = total length of edge of cover types that provide winter cover/food; A = total area of study site. DI values ≥ 1.5 are assumed to represent optimum interspersion conditions for the easter cottontail).	Entire study area	Remote sensing, cover type map, planimeter, ruler

Figure 6. (concluded).

SOURCES OF OTHER MODELS

Urich et al. (1983) have compiled a series of habitat evaluation models, including a eastern cottontail model, applicable for habitat analysis in Missouri.

REFERENCES

Anderson, B. F., and M. R. Pelton. 1976. Movements, home range, and cover use: Factors affecting the susceptibility of cottontails to hunting. Proc. Southeastern Assoc. Game and Fish Commissioners 30:525-535.

Beckwith, S. L. 1954. Ecological succession on abandoned farm lands and its relationship to wildlife management. Ecol. Monogr. 24(4):349-376.

Bigham, S. R. 1966. Identification of the habitat of the cottontail rabbit in central Oklahoma. Oklahoma Dept. Wildl. Conserv., Job Completion Rep. W-89-R-1. 9 pp.

________________. 1970. The comparative utility of plant life-form and other vegetational characteristics in evaluating the habitat of the cottontail. Ph.D. Diss., Oklahoma State Univ., Stillwater 77 pp. [Abstract only, from Diss. Abstr. Int. B. Sci. Eng. 31(11):6991-B, 1971].

Bruch, D., and J. A. Chapman. 1983. Social behavior of the eastern cottontail, Sylvilagus floridanus (Lagomorpha:Leporidae) in a woodland habitat, with descriptions of new behavior. Proc. Pennsylvania Acad. Sci. 57(1):74-78.

Bruna, J. F. 1952. Kentucky rabbit investigations. Fed. Aid Proj. 26-R. Frankfort, KY. 83 pp. Cited by Chapman et al. 1982.

Chapman, J. A. 1971. Orientation and homing of the brush rabbit (Sylvilagus bachmani). J. Mammal. 52(4):686-699.

Chapman, J. A., J. G. Hockman, and W. R. Edwards. 1982. Cottontails. Pages 83-123 in J. A. Chapman and G. A. Feldhamer, eds. Wild mammals of North America: Biology, management, economics. Johns Hopkins Univ. Press, Baltimore, MD. 1,147 pp.

Chapman, J. A., J. G. Hockman, and M. M. Ojeda C. 1980. Sylvilagus floridanus. Mammal. Species 136:1-8.

Chapman, J. A., and R. T. Morgan. 1973. Systematic status of the cottontail complex in western Maryland and nearby West Virginia. Wildl. Monogr. 36. 54 pp.

DeCalesta, D. S. 1971. A literature review on cottontail feeding habits. Colorado Div. Game Fish Parks, Spec. Rep. 25. 15 pp.

Dusi, J. L. 1952. The food habits of several populations of cottontail rabbits in Ohio. J. Wildl. Manage. 16(1):180-186.

Eberhardt, L. L., T. J. Peterle, and R. Schofield. 1963. Problems in a rabbit population study. Wild. Monogr. 10:1-51.

Edwards, W. R., S. P. Havera, R. F. Labisky, J. A. Ellis, and R. E. Warner. 1981. The abundance of cottontails in relation to agricultural land use in Illinois (U.S.A.) 1956-1978, with comments on mechanism of regulation. Proc. World Lagomorph Conf. 1:761-789. August 1979. Guelph, Ontario. 983 pp.

Ellis, J. A., W. R. Edwards, and K. P. Thomas. 1969. Responses of bobwhites to management in Illinois. J. Wildl. Manage. 33(4):749-762.

Friley, C. E. 1955. A study of cottontail habitat preferences on a southern Michigan farming area. Fed. Aid Proj. W-48-R. 20 pp.

Hansen, J. C., J. A. Bailey, and R. J. Siglin. 1969. Activity and use of habitat by radio tagged cottontails during winter. Illinois Acad. Sci. Trans. 62(3):294-302.

Haugen, A. O. 1942. Life history studies of the cottontail rabbit in southwestern Michigan. Am. Midl. Nat. 28:204-244.

Hays, R. L., C. S. Summers, and W. Seitz. 1981. Estimating wildlife habitat variables. U.S. Fish Wildl. Serv., FWS/OBS-81/47. 111 pp.

Heard, L. P. 1962. Job completion report, rabbit studies (cottontail). Pittman-Robertson Proj. W-48-R-8, Mississippi. 25 pp.

Hendrickson, G. O. 1940. Nesting cover used by Mearns cottontails. Trans. North Am. Wildl. Conf. 5:328-331.

Janes, D. W. 1959. Home range and movements of the eastern cottontail in Kansas. Univ. Kansas Publ., Mus. Nat. Hist. 10(7):553-572.

Kline, P. D., and G. O. Hendrickson. 1954. Autumnal decimation of Mearns cottontail, Decatur Co., Iowa, 1952. Proc. Iowa Acad. Sci. 61:524-527.

Korschgen, L. J. 1980. Food and nutrition of cottontail rabbits in Missouri. Missouri Dept. Conserv. Terrestrial Ser. 6. 16 pp.

Lord, R. D. 1963. The cottontail rabbit in Illinois. Illinois Dept. Conserv. Tech. Bull. 3. 94 pp.

Madson, J. 1959. The cottontail rabbit. Olin Matherson Chemical Corp., East Alton, IL. 56 pp. Cited by Chapman et al. 1982.

Morgan, K. A., and J. E. Gates. 1983. Use of forest edge and strip vegetation by eastern cottontails. J. Wildl. Manage. 47(1):259-264.

Morgan, K. A. Personal communication (letter dated 5 July 1984). Wisconsin Dept. Nat. Resour., Brule Area Headquarters, Box 125, Brule, WI 59820.

Nugent, R. F. 1968. Utilization of fall and winter habitat by the cottontail rabbits of northwestern Connecticut. Agric. Exp. Stn., Univ. Connecticut, Stores. 34 pp.

Pils, C. M., M. A. Marten, and L. R. Peterson. 1981. Experimental cottontail habitat management on the Brooklyn Wildlife Area. Wisconsin Dept. Nat. Resourc. Res. Dept. 108. 18 pp.

Podoll, E. B. 1979. Utilization of windbreaks by wildlife. Pages 121-127 _in_ K. Thompson and E. Varley, eds. Proc. of Great Plains Forestry Committee windbreak management workshop. October 23-25, 1979. Norfolk, NE. Great Plains Agric. Council Publ. 92.

Schwartz, C. W., and E. R. Schwartz. 1959. The wild mammals of Missouri. Univ. Missouri Press, Kansas City. 341 pp.

Smith, R. H. 1950. Cottontail rabbit investigations. Pittman-Robertson Proj. 1-R. New York. 84 pp.

Sweetman, H. L. 1944. Selection of woody plants as winter food by the cottontail rabbit. Ecology 25(4):467-472.

Swihart, R. K. 1981. Use of farmland habitat patches by the eastern cottontail. M.S. Thesis, Univ. Minnesota, St. Paul. 75 pp.

______________. Personal communication (letter dated 11 June 1984). University of Kansas, Museum of Natural History, Lawrence, KS 66045.

Swihart, R. K., and R. H. Yahner. 1982a. Eastern cottontail use of fragmented farmland habitat. Acta. Theriologica 27(19):257-273.

______________. 1982b. Habitat features influencing use of farmstead shelterbelts by the eastern cottontail (Sylvilagus floridanus). Am. Midl. Nat. 107(2):411-414.

______________. 1982-1983. Browse use by eastern cottontails in a southeast Minnesota farmstead shelterbelt. J. Minn. Acad. Sci. 48(2):13-15.

______________. 1983. Browse preferences of jackrabbits and cottontails for species used in shelterbelt plantings. J. For. 81(2):92-94.

Trent, T. T., and O. J. Rongstad. 1974. Home range and survival of cottontail rabbits in southwestern Wisconsin. J. Wildl. Manage. 38(3):459-472.

Urich, D. L., J. P. Graham, and C. C. Cook. 1983. A handbook for habitat evaluation in Missouri. Missouri Dept. Conserv. 148 pp.

U.S. Fish and Wildlife Service. 1981. Standards for the development of habitat suitability index models. 103 ESM. U.S. Fish Wildl. Serv., Div. Ecol. Serv. n.p.

Vance, D. R. 1976. Changes in land use and wildlife populations in southeastern Illinois. Wildl. Soc. Bull. 4(1):11-15.

Verts, B. J., and L. N. Carraway. 1981. Dispersal and dispersion of an introduced population of Sylvilagus floridanus. Great Basin Nat. 41(2):167-175.

Wegner, J. F., and G. Merriam. 1979. Movements by birds and small mammals between a wood and adjoining farmland habitats. J. Applied Ecol. 16(1):349-357.

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. 82/10.66	2.	3. Recipient's Accession No.
4. Title and Subtitle Habitat Suitability Index Models: Eastern Cottontail			5. Report Date July 1984 6.
7. Author(s) Arthur W. Allen			8. Performing Organization Rept. No.
9. Performing Organization Name and Address	Western Energy and Land Use Team U.S. Fish and Wildlife Service Drake Creekside Building One 2627 Redwing Road Fort Collins, CO 80526-2899		10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address	Western Energy and Land Use Team Division of Biological Services Research and Development Fish and Wildlife Service U.S. Department of the Interior Washington, DC 20240		13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This report presents information on the key environmental variables influencing the suitability of a particular habitat for Eastern cottontail (*Sylvilagus floridanus*). A habitat model is developed which is scaled to produce a suitability index between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). This information is useful for impact assessment and habitat management.

17. Document Analysis a. Descriptors

Wildlife
Habitability
Mathematical models

b. Identifiers/Open-Ended Terms

Eastern cottontail
Habitat suitability
Sylvilagus floridanus

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release unlimited	Unclassified	23
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI–Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4–77) (Formerly NTIS–35) Department of Commerce

☆ U.S. GOVERNMENT PRINTING OFFICE: 1985—576-937/25059 REGION NO. 8

DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

Great Trinity Forest Management Plan

Wildlife Management

Eastern Meadowlark

(Sturnella magna)

Eastern Meadowlark
(*Sturnella magna*)

The Eastern meadowlark is one of the most widely distributed songbirds and occurs from southeastern Canada to northern South America. Predators include hawks, cats, dogs, foxes and skunks. (Lanyon 1995)

Food

This species is an omnivorous ground feeder which mainly (~74% of diet) feeds on insects such as crickets and grasshoppers in fall and caterpillars, cutworms and grubs in the spring. The remainder of its diet is vegetable matter which is mainly grain and weed seeds such as smartweed (*Polygonum* spp), ragweed (*Ambrosia* sp), corn, wheat, rye, and oats. However, wild fruit, such as wild cherries (*Prunus* spp), strawberries (*Fragaris* spp) and blackberries (*Rubus* spp), may also be consumed. Nestlings are fed almost exclusively insects by their parents (Schroder and Sousa 1982, Lanyon 1995).

Water

Its drinking water requirements are unknown but captive eastern meadowlarks do use free water (Schroder and Sousa 1982).

Habitat

Eastern meadowlark is a grassland bird that is found in grasslands, meadows, pastures and savannas, but it also may use cropland or abandoned fields if the shrub cover is less than 35%. Optimal habitat is "herbaceous cover types dominated by grasses of moderate heights with low shrub densities and adequate numbers of perches" (Schroder and Sousa 1982). Ribici and Sample (2001) found that even though density of this grassland species is positively associated with woody vegetation, its density decreases the closer the habitat is to woodlots. Schroder and Sousa (1982) reports that grazed grasslands between 10 - 30 cm tall (4 - 12 in) with scattered forbs had the most use, while areas dominated by forbs had little use. Several studies found that range size can vary from 1.2 - 6.1 ha (3 - 15 ac) but the average range was 2.8 - 3.2 ha (7 - 8 ac) (Schroder and Sousa 1982, Lanyon 1995).

Reproduction

This species nests in grassland habitat with fairly dense vegetation by constructing a dome-shaped roof of grass over a shallow depression. Nest sites usually occur in dense vegetation with dead grass stems at ground level and no woody vegetation in the immediate area. One study on nest site selection found that this species selects sites with abundant litter and away from bare ground, woody vegetation and edge habitat. In a study conducted in Illinois the average height of nesting cover was 38 cm (15in) with the majority of nests occurring in cover that was 25 - 50 cm (10 - 20 in) high. The same study found that the "density of nesting meadowlarks in pastures was inversely related to the intensity of grazing" (Schroder and Sousa 1982). Threats to nests include domestic cats and dogs, parasitism by brown headed cowbird, mowing and trampling by humans and livestock. In fact, this species is very sensitive to humans in its breeding territory and may abandon a nest if it only has eggs. Perch sites are also important for lookout perches and for males to use as singing perches (Schroder and Sousa 1982, Lanyon 1995, Hubbard et al 2006).

Management

To provide optimal breeding season habitat the herbaceous canopy cover should be great than 90% and more than 80% of the herbaceous canopy cover should be grass. The average height of the herbaceous canopy (its average spring condition) should be 12.5 -35 cm (5 - 14 in) and it should have enough variation to provide nesting, loafing and feeding sites. This can be achieved by moderately grazing the area using a rotational system; but, severe grazing (less than 10 cm) will discourage use be meadowlarks. Grazing during the nesting season should be avoided since cattle can damage nests and trample eggs and nestlings. In fact, a study on grassland bird predation by Nack and Ribic (2005) found that 33.3% of the failed nests were caused by cattle. Mowing may also be used every 3 - 5 years but it should be delayed until August. Prescribed burning may also be used to eliminate litter, increase grass density, decrease woody vegetation and decrease forb abundance and diversity. Burn intervals for tall grass prairies average every 2 to 5 years but this species can tolerate much longer intervals. Perch sites, such as fence posts, shrubs and tall forbs, are also important and ideally there should be 1 at least every 30 m (100 ft). Optimum shrub crown cover is less than 5% and areas with more than 35% are considered unsuitable (Schroder and Sousa 1982, Lanyon 1995, Powell 2006).

Literature Cited

Hubbard, R.D., D.P. Althoff, K.A. Blecha, B.A. Bruvold and R.D. Japuntich. 2006. Nest site characteristics of eastern meadowlarks and grasshopper sparrows in tallgrass prairie at the Fort Riley military installation,Kansas. Transactions of the Kansas Academy of Science Vol. 109, no. ¾ p. 168-174

Lanyon, W. E. 1995. Eastern Meadowlark (*Sturnella magna*). *In* The Birds of North America, No. 160 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

Nack,. J.L and C.A. Ribic. 2005. Apparent Predation By Cattle at Grassland Bird Nests. Wilson Bulletin 117(1):56–62, 2005

Powell, A.F.L.A. 2006. Effects of Prescribed Burns and Bison (*Bos bison*) Grazing on Breeding Bird Abundances In TallGrass Prairie. The Auk 123(1):183–197

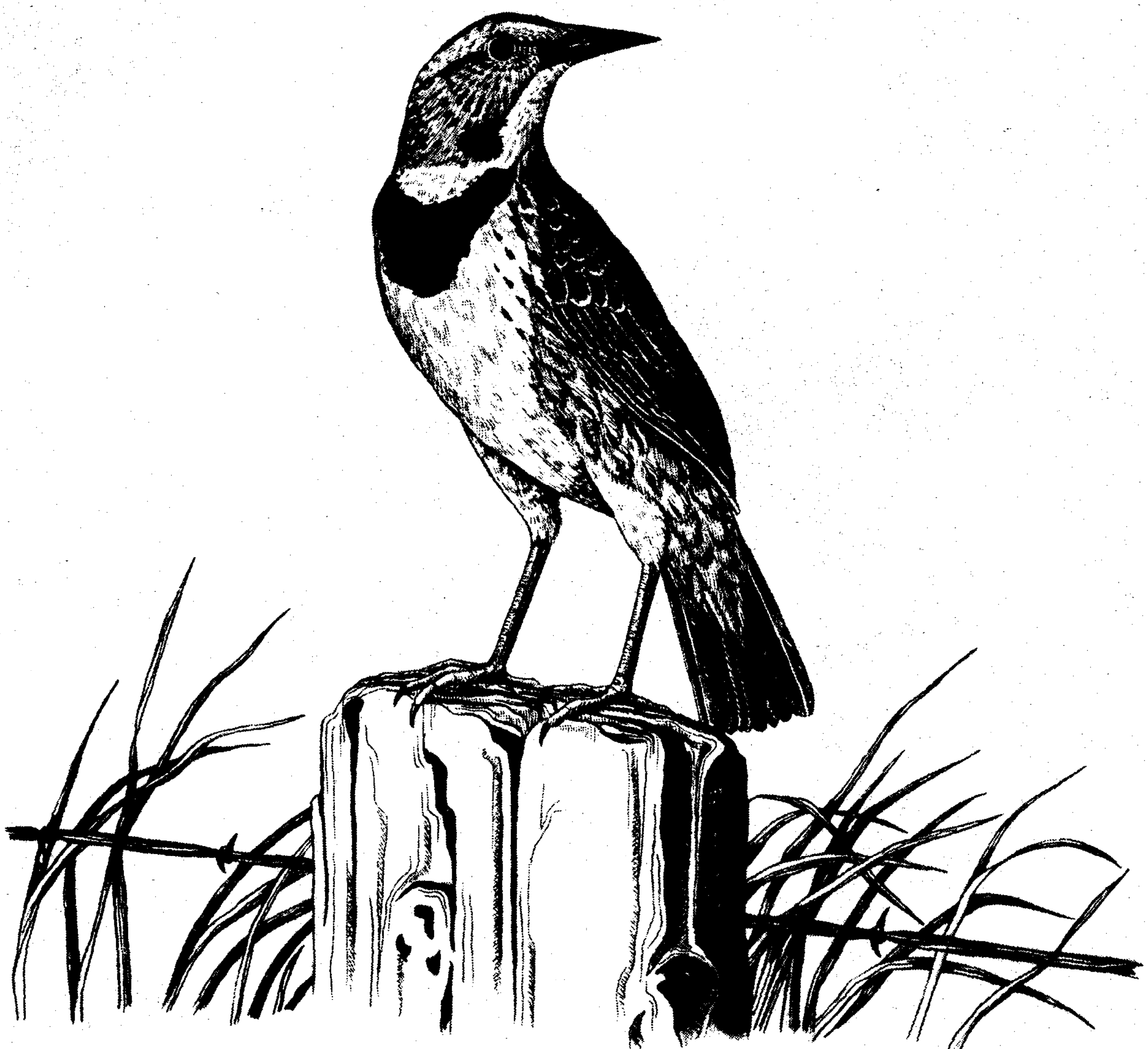
Ribici, C.A and D.W. Sample. 2001. Associations of Grassland Birds with Landscape Factors in Southern Wisconsin. Am. Midl. Nat. 146:105–121

Schroeder, R.L., and P.J. Sousa. 1982. Habitat Suitability Index Models: Eastern Meadowlark. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.29. 9 pp.

Biological Services Program
and
Division of Ecological Services

FWS/OBS-82/10.29
SEPTEMBER 1982

HABITAT SUITABILITY INDEX MODELS: EASTERN MEADOWLARK



Fish and Wildlife Service

U.S. Department of the Interior

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues that impact fish and wildlife resources and their supporting ecosystems. The mission of the program is us follows:

- To strengthen the Fish and Wildlife Service in its role as a primary source of information on national fish and wildlife resources, particularly in respect to environmental impact assessment.
- To gather, analyze, and present information that will aid decisionmakers in the identifica tin and resolution of problems associated with major changes in land and water use.
- To provide better ecological information and evaluation for Department of the Interior development programs; such as those relating to energy development.

Information developed by the Biological Services Program is intended for use in the planning and decisionmaking process to prevent or minimize' the impact of development on fish and wildlife. Research activities and technical assistance services are based-on an analysis of the issues, a determination of the decisionmakers involved and their information needs, and an evaluation of the state of the art to identify information gaps and to determine priorities. This is astrategy that will ensure that the products produced and disseminated are timely an&useful.

Projects have been initiated in the following areas: coal extraction and conversion; power plants; geothermal, mineral and oil shale development; water resource analysis, including stream alterations'and western water allocation; coastal ecosystems and Outer Continental, Shelf development; and systems inventory, including National Wetland Inventory, habitat classification and analysis, and information transfer.

The Biological Services Program consists of the Office of Biological Services in Washington, O.C., which is responsible for overall planning and management; National Teams, which provide the Program's central scientific and technical expertise and arrange for contracting biological services studies with states, universities, consulting firms, and others; Regional Staffs, who provide a link to problems at the operating level; and staffs at certain Fish and Wildlife Service research facilities, who conduct in-house research studies.

This model is designed to be used by the Division of Ecological Services in conjunction with the Habitat Evaluation Procedures.

FWS/OBS-82/10.29
September 1982

HABITAT SUITABILITY INDEX MODELS: EASTERN MEADOWLARK

by

Richard L. Schroeder
and
Patrick J. Sousa
Habitat Evaluation Procedures Group
Western Energy and Land Use Team
U.S. Fish and Wildlife Service
Drake Creekside Building One
2625 Redwing Road
Fort Collins, CO 80526

Western Energy and Land Use Team
Office of Biological Services
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

This report should be cited as:

Schroeder, R. L., and P. J. Sousa. 1982. Habitat suitability index models: Eastern meadowlark. U.S. Dept. Int,, Fish Wildl. Serv. FWS/OBS-82/10.29. 9 pp.

PREFACE

This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for HSI models that follow. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model Section documents a habitat model and information pertinent to its application. The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The application information includes descriptions of the geographic ranges and seasonal application of the model, its current verification status, and a listing of model variables with recommended measurement techniques for each variable.

In essence, the model presented herein is a hypothesis of species-habitat relationships and not a statement of proven cause and effect relationships. Results of model performance tests, when available, are referenced. However, models that have demonstrated reliability in specific situations may prove unreliable in others. For this reason, feedback is encouraged from users of this model concerning improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning. Please send suggestions to:

Habitat Evaluation Procedures Group
Western Energy and Land Use Team
U.S. Fish and Wildlife Service
2625 Redwing Road
Ft. Collins, CO 80526

CONTENTS

ACKNOWLEDGMENTS

We gratefully acknowledge Fred Alsop for his review of this habitat model and Jean O'Neil of the U.S. Army Corps of Engineers Waterways Experiment Station for assisting with model review efforts. The cover of this document was illustrated by Jennifer Shoemaker. Word processing was provided by Carolyn Gulzow and Dora Ibarra.

EASTERN MEADOWLARK (Sturnella magna)

HABITAT USE INFORMATION

General

The eastern meadowlark (Sturnella magna) is an omnivorous ground feeder (Willson 1974) that nests in open fields throughout the eastern and south-central United States (Robbins et al. 1966).

Food

Approximately 74% of the annual diet consists of animal matter and includes mainly beetles, grasshoppers, caterpillars, and occasionally flies, wasps, and spiders (Beal 1926, cited by Gross 1958). Crickets and grasshoppers comprise 26% of the annual diet, and beetles make up 25% of the annual diet. The remainder of the diet consists of vegetable matter, mainly grain and weed seeds. Seeds of smartweed (Polygonum spp.), ragweed (Ambrosia spp.), corn, wheat, rye, and oats are eaten in the winter months when insects are scarce (Gross 1958). Fruits, such as wild cherries (Prunus spp.), strawberries (Fragaria spp.), and blackberries (Rubus spp.), may also constitute a small percentage of the diet. During adverse winter weather, eastern meadowlarks have been observed to feed on road kills (Hubbard and Hubbard 1969).

Water

No data on drinking water requirements for the eastern meadowlark were located in the literature, although captive eastern meadowlarks do bathe in and drink free water (Gross 1958).

Cover

The eastern meadowlark is primarily found in grasslands, meadows, and pastures (Gross 1958). Meadowlarks inhabited old field successional stages in Georgia from 1 (grass-forb) to 15 years (grass-shrub) after the fields were no longer farmed (Johnston and Odum 1956). This species inhabited fields where shrub coverage was less than 35%, regardless of grass cover in the area. Feeding and loafing cover areas in Missouri that had high use were characterized as grasslands with no forbs or scattered forbs present, while areas where forbs were dominant had little use (Skinner 1975). Maximum use was observed in grazed grasslands between 10 and 30 cm tall (4 and 12 inches), with scattered forbs present.

Reproduction

The preferred nesting habitat of the eastern meadowlark in Illinois was pasture, followed in descending order by hayfields, soilbank fields, winter wheat fields, idle areas, and fallow areas (Roseberry and Klimstra 1970). The density of nesting meadowlarks in pastures was inversely related to the intensity of grazing. Highest nesting densities occurred during the 2 years when pastures were not grazed, and numerous dead grass stems and vigorous stands of grass (fescue) were present. Nesting densities in haylands were highest in a mixed-grass hayfield. Use of alfalfa fields, wheat fields, and fallow areas for nesting was low because these areas lacked sufficient grassy cover to provide suitable nesting habitat. Idle areas were little used when shrubs and trees became abundant. The average height of nesting cover was 38 cm (15 inches), with the majority of nests located in cover 25 to 50 cm (10 to 20 inches) high. The presence of dead grass stems at ground level and the absence of woody vegetation or numerous shrubs in the immediate vicinity of the nest site seemed necessary for nesting.

Nests of the eastern meadowlark are built in shallow depressions and have a dome-shaped roof constructed of grass, frequently interwoven with clumps of grasses or weeds (Gross 1958). Elevated singing and lookout perches, such as telephone wires, electric power lines, mounds of earth, farm implements, or fence posts, are used by males.

Interspersion

Meadowlark territories in Wisconsin varied in size from 1.2 to 6.1 ha (3 to 15 acres) and were commonly 2.8 to 3.2 ha (7 to 8 acres) (Lanyon 1956). The average size of 15 territories in New York was 2.8 ha (7 acres) (Gross 1958).

Special Considerations

Domestic cats and dogs prey on the eggs and young of the eastern meadowlark, and close proximity of nesting sites to human habitations is undesirable (Lanyon 1957). Mowing and heavy grazing by livestock may destroy meadowlark nests (Roseberry and Klimstra 1970).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model was developed for application within the breeding range of the eastern meadowlark.

Season. This model was developed to evaluate the breeding season habitat of the eastern meadowlark.

Cover types. This model was developed to evaluate habitat quality in the following cover types: Pasture and Hayland (P/H); Grassland (G); and Forbland (F) (terminology follows that of U.S. Fish and Wildlife Service 1981).

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before a species will occupy an area. Specific information on minimum areas required for eastern meadowlarks was not found in the literature. Based on home range data, it is assumed that a minimum of 1.2 ha (3.0 acres) of habitat must exist or the HSI will equal zero.

Verification level. Previous drafts of this model were reviewed by Fred Alsop, and his specific comments were incorporated into the current draft (Alsop, pers. comm.).

Model Description

Overview. This model considers the feeding and reproductive needs of the eastern meadowlark to determine overall habitat quality and assumes that these two life requisites can be combined to assess habitat. It is assumed that cover needs are met by the feeding and reproductive habitat needs and that water will not be a limiting factor. All of the life requirements of the eastern meadowlark can be provided within each cover type in which it occurs.

The relationship between habitat variables, life requisites, cover types, and the HSI for the eastern meadowlark is illustrated in Figure 1.

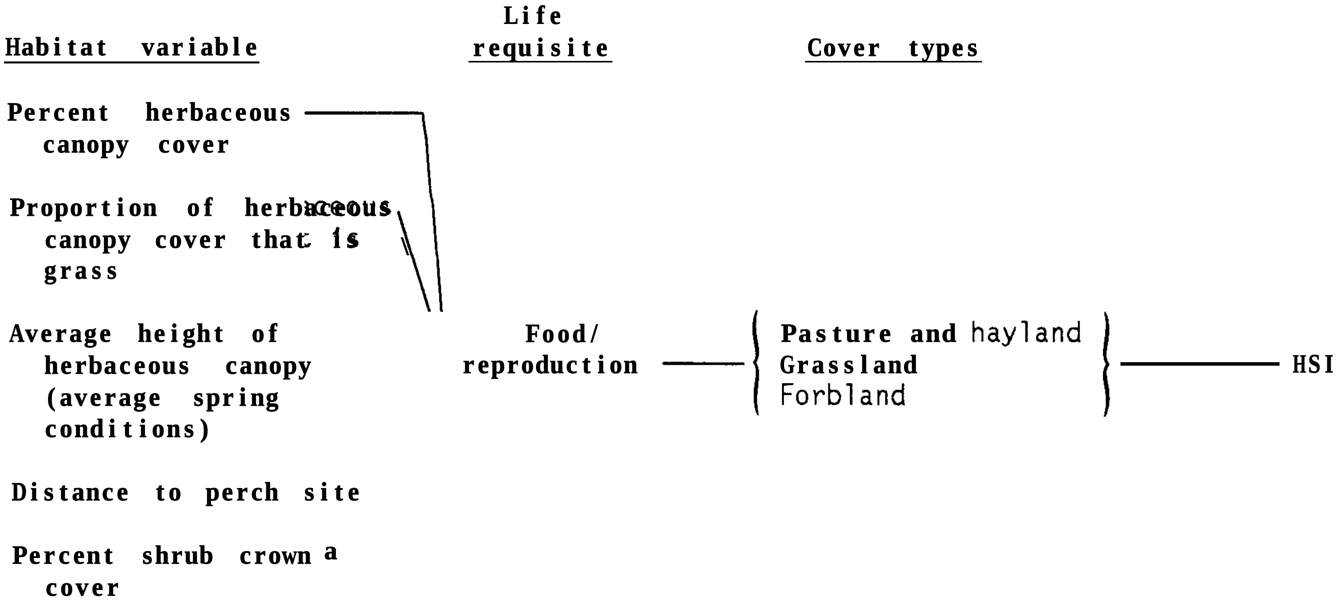


Figure 1. Relationships of habitat variables, life requisites, and cover types in the eastern meadowlark model.

The following sections provide a written documentation of the logic and assumptions used to interpret the habitat information for the eastern meadowlark in order to explain and justify the variables and equations that are used in the HSI model. Specifically, these sections cover the following: (1) identification of variables that will be used in the model; (2) definition and justification of the suitability levels of each variable; and (3) description of the assumed relationship between variables.

Food/reproduction component. Feeding and reproductive habitat suitability for the eastern meadowlark is related to the height and density of herbaceous vegetation, the abundance of grasses, the presence of shrubs, and the proximity of perch sites. Optimal habitats occur in herbaceous cover types dominated by grasses of moderate heights with low shrub densities and adequate numbers of perches. Meadowlarks prefer very dense vegetation, and optimal herbaceous densities are assumed to occur at greater than 90% canopy cover. Suitability will decrease as the total herbaceous canopy cover decreases, and habitats will not be suitable at canopy covers of less than 20%. Data in the literature indicate that the best habitats are in grasslands with few forbs and that meadowlarks avoid areas where forbs are predominant. It is assumed that optimal conditions will exist when greater than 80% of the herbaceous cover is grass, that suitability will decrease as the relative percent of grass decreases, and that the habitat will not be suitable when less than 20% of the herbaceous cover is grass.

Data in the literature indicate that ideal vegetative heights for foraging and loafing are between approximately 10 and 30 cm (4 and 12 inches) and that the best heights for nesting are between 25 and 50 cm (10 and 20 inches). It is assumed that a large majority of the habitat should be suitable for foraging and loafing to have optimal habitat conditions. Therefore, it is assumed that the best habitats will have an average spring season canopy height of between 12.5 and 35 cm (5 and 14 inches). It is assumed that there will be enough variation in the actual canopy height so that there is a high likelihood of both suitable feeding and nesting heights being present if the average height falls within the range indicated. It is further assumed that, if the average height is less than 2.5 cm (1.0 inches) or greater than 76 cm (30 inches), no suitability will exist.

Ideal meadowlark habitats contain an abundance of perch sites, such as tall forbs, shrubs, trees, fences, or telephone wires. These perches can be within the cover type or on the periphery, such as a forest edge. It is assumed that optimal conditions exist when the average distance from random points in the cover type being evaluated to a suitable perch is less than 30 m (100 ft). This is equivalent to about four perches per 1.2 ha (3.0 acres), the minimum habitat area for the eastern meadowlark. It is assumed that suitability will decrease as the distance to perch sites increases to 60 m (ZOO ft), which is equal to about one perch site per 1.2 ha (3.0 acres). Some habitat suitability may exist even when there are no apparent perch sites, because of the adaptability of the meadowlark in selecting perches.

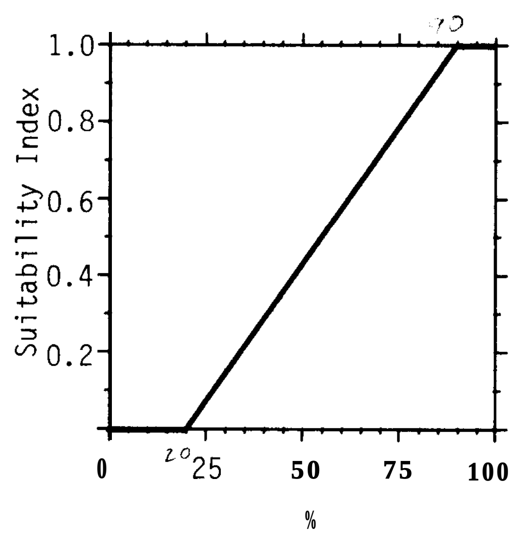
Suitability of the herbaceous component of the habitat is related to the total herbaceous cover, the relative grass cover, the height of herbaceous vegetation, and the proximity of perch sites. It is assumed that each variable exerts a major influence on overall habitat suitability. A habitat must contain optimal levels of all variables to have maximum suitability. Low values of any one variable may be partially offset by higher values of the remaining variables. Habitats with low values for two or more of these variables will have low suitability levels.

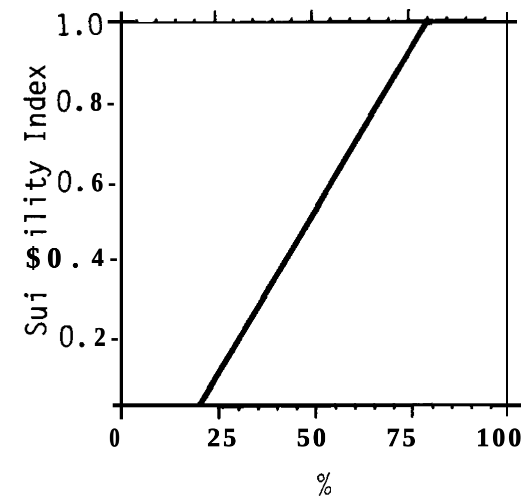
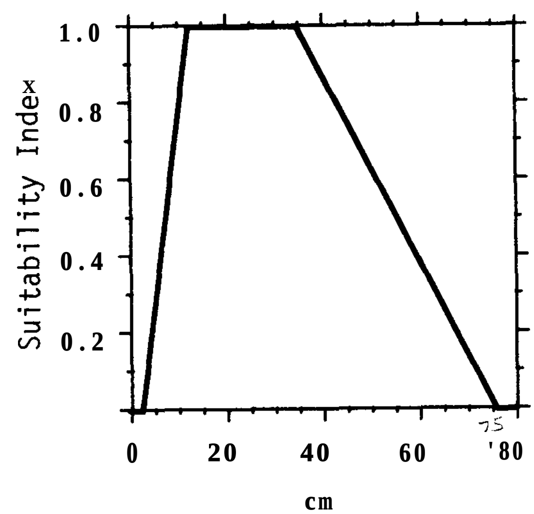
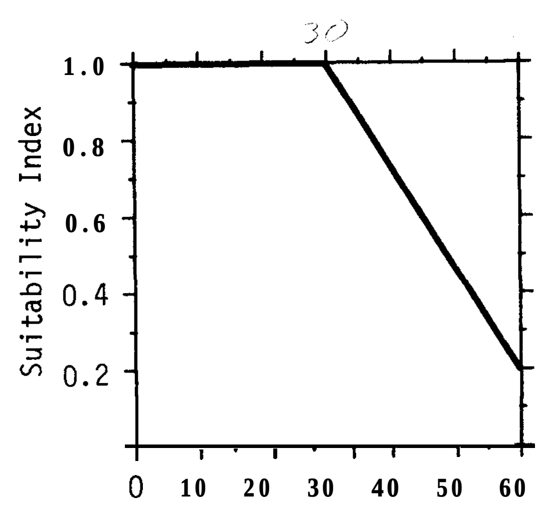
The presence of a moderate or dense shrub cover is a negative influence in meadowlark habitat selection. Optimal habitats contain less than 5% shrub canopy; suitability will decrease as shrub densities increase, and habitat will not be suitable at shrub densities greater than 35%.

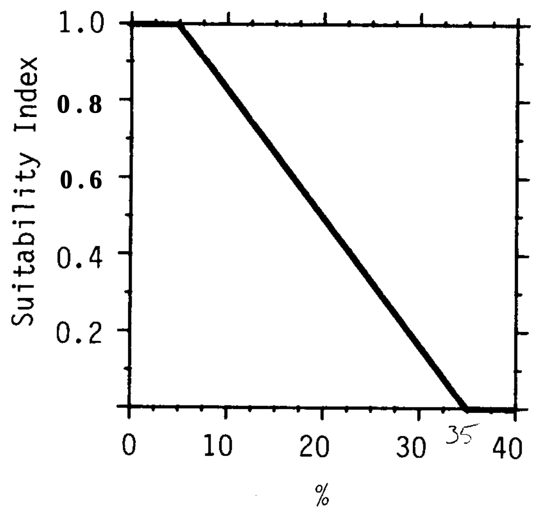
Overall habitat suitability is related to the quality of the herbaceous component described above and the abundance of shrubs. It is assumed that, as shrub densities. increase above 5%, the overall habitat value will decrease, regardless of the quality of the herbaceous component.

Model Relationships

Suitability Index (Si) graphs for habitat variables. This section contains suitability index graphs that illustrate the habitat relationships described in the previous section.

Cover Type	Variable		
P/H,G, F	V_1	Percent herbaceous canopy cover.	

P/H,G, F	V_2	Proportion of herbaceous canopy cover that is grass.	
P/H, G, F	V_3	Average height of herbaceous canopy (average spring conditions).	
P/H,G, F	V_4	Distance to perch site (such as tall forb, shrub, tree, fence, or telephone wires).	

P/H,G,F	V_5	**Percent shrub crown cover.**	

<u>Equations</u>. In order to determine life requisite values for the eastern meadowlark, the SI values for appropriate variables must be combined through the use of eauations. A discussion and explanation of the assumed relationships between variables was included under <u>Model Description</u>, and the specific equation in this model was chosen to mimic these perceived biological relationships as closely as possible. The suggested equation for obtaining the food/reproduction value is presented below.

Life requisite	Cover type	Equation
Food/Reproduction	P/H,G,F	$(V_1 \times V_2 \times V_3 \times V_4)^{1/2} \times V_5$

<u>HSI determination</u>. The HSI for the eastern meadowlark is equal to the life requisite value for food/reproduction.

Application of the Model

Definitions of variables and suggested field measurement techniques (Hays et al. 1981) are provided in Figure 2.

Variable (definition)		Cover types	Suggested techniques
V_1	Percent herbaceous canopy cover (the percent of the ground that is shaded by a vertical projection of all nonwoody vegetation).	P/H,G,F	Line intercept
V_2	Proportion of herbaceous canopy cover that is grass (the relative percent of all herbaceous cover that is comprised of grasses).	P/H,G,F	Line intercept
V_3	Average height of herbaceous canopy (average spring conditions) (the average vertical distance from the ground surface to the dominant height stratum of the herbaceous vegetative canopy during average spring conditions).	P/H,G,F	Line intercept, graduated rod
V_4	Distance to perch site (such as tall forb, shrub, tree, fence, or telephone wires) (the average distance from random points to the nearest suitable perch site, within or outside the boundaries of the cover type).	P/H,G,F	Pacing
V_5	Percent shrub crown cover (the percent of the ground that is shaded by a vertical projection of the canopies of woody vegetation less than 5 m (16.5 ft) in height).	P/H,G,F	Line intercept

Figure 2. Definitions of variables and suggested measurement techniques.

SOURCES OF OTHER MODELS

No other habitat models for the eastern meadowlark were identified.

REFERENCES

Alsop, F. pers. comm. (16 July 1981). East Tennessee State University, Kingsport, Tennessee.

Beal, F. E. L. 1926. Some common birds useful to the farmer. U.S.D.A. Farmer's Bull. 630. Cited by Gross 1958.

Gross, A. O. 1958. Eastern meadowlark. Pages 53-80 in A. C. Bent. Life histories of North American blackbirds, orioles, tanagers, and allies. U.S. Natl. Mus. Bull. 211.

Hays, R. L., C. S. Summers, and W. Seitz. 1981. Estimating wildlife habitat variables. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-81/47. 173 pp.

Hubbard, J. P., and C. L. Hubbard. 1969. Meadowlarks feeding on road-kills. Wilson Bull. 81(1):107-108.

Johnston, D. W., and E. P. Odum. 1956. Breeding bird populations in relation to plant succession on the piedmont of Georgia. Ecology 37(1):50-62.

Lanyon, W. E. 1956. Territory in the meadowlarks, genus Sturnella. Ibis 98:485-489.

______________. 1957. The comparative biology of the meadowlarks (Sturnella) in Wisconsin. Publ. Nuttall Ornithol. Club 1. Cambridge, Mass. 67 pp.

Robbins, C. S., B. Bruun, and H. S. Zim. 1966. A guide to field identification, Birds of North America. Golden Press, N.Y. 340 pp.

Roseberry, J. L., and W. D. Klimstra. 1970. The nesting ecology and reproductive performance of the eastern meadowlark. Wilson Bull. 82(2):241-267.

Skinner, R. M. 1975. Grassland use patterns and prairie bird populations in Missouri. Pages 171-180 in M. K. Wali, ed. Prairie: a multiple view. Univ. North Dakota Press, Grand Forks.

U.S. Fish and Wildlife Service. 1981. Standards for the development of habitat suitability index models. 103 ESM. U.S. Dept. Int., Fish Wildl. Serv., Division of Ecological Services. n.p.

Willson, J. F. 1974. Avian community organization and habitat structure. Ecology 55:1017-1029.

0272 -101

REPORT DOCUMENTATION PAGE	1. REPORT NO. FWS/OBS-82/10.29	2.	3. Recipient's Accession No.
4. Title and Subtitle Habitat Suitability Index Models: Eastern Meadowlark			5. Report Date September 1982
			6.
7. Author(s) Richard L. Schroeder and Patrick J. Sousa			8. Performing Organization Rept. No.
9. Performing Organization Name and Address	Habitat Evaluation Procedures Group Western Energy and Land Use Team U.S. Fish and Wildlife Service Drake Creekside Building One 2625 Redwing Road Fort Collins, CO 80526		10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address	Western Energy and Land Use Team Office of Biological Services Fish and Wildlife Service U.S. Department of the Interior Washington. DC 20740		13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

Habitat preferences of the eastern meadowlark (Sturnella magna) are described in this publication, which is one of a series of Habitat Suitability Index (HSI) models. Habitat use information is presented in a synthesis of the literature on the species-habitat requirements of the eastern meadowlark, followed by the development of the HSI model. The model is presented in three formats: graphic, word, and mathematical, and is designed to provide information for use in impact assessment and habitat management activities.

17. Document Analysis a. Descriptors

Animal behavior
Habit
Habitability
Mathematical models
Birds
Wildlife

b. Identifiers/Open-Ended Terms

Eastern meadowlark
Sturnella magna
Habitat Suitability Index (HSI)
Species-habitat requirements
Impact assessment
Habitat management

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
RELEASE UNLIMITED	UNCLASSIFIED	ii - v +9pp
	20. Security Class (This Page) UNCLASSIFIED	22. Price

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

☆U.S. GOVERNMENT PRINTING OFFICE: 1982-0-580-666/450

DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our natiinal parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

Great Trinity Forest Management Plan

Wildlife Management

Fox Squirrel

(Sciurus niger)

Fox Squirrel
(*Sciurus niger*)

The fox squirrel is the largest of the North American tree squirrels and is generally 19 - 28 inches long. This tree squirrel occurs in the eastern United States but it has been introduced in the West. Predators of this species include red tailed hawk (*Buteo jamaicensis*), bobcats (*Lyns rufus*), foxes and owls; but the biggest "predators" is probably the automobile (Weigl 1989, MacClintock 1970, Allen 1982).

Food

Fox squirrels eat a variety of food such as tree buds, bird eggs, insects, sap, mushrooms, bulbs, twigs and roots. They also eat a variety of hard and soft mast from many species such as hickory (*Carya* spp.), oaks (*Quercus* spp.), walnuts (*Juglans* spp.), American beech (*Fagus grandifolia*), dogwood (*Cornus* spp.) and black cherry (*Prunus serotina*). If available, this species will also use crops such as corn and oats (MacClintock 1970, Allen 1982).

Water

Fox squirrels generally obtain most of their water from their diet but may use free water (Allen 1982).

Habitat

Fox squirrels prefer open forest with little understory vegetation and in Texas they are often associated with uplands and well-drained bottomlands. This is an adaptable species that is also common in urban environments and can be considered a pest. A study conducted by McCleery et al. (2007) found that squirrels in an urban setting selected areas with a greater tree canopy and larger trees, especially oaks species. They found that the species also used grassy areas for cashes and buildings for shelter in the winter. The range of the fox squirrel in the southeast is usually 2 - 4 ha (5-10 ac) (Allen 1982).

Reproduction

This species usually has 3 nests, one of which is a tree cavity. These cavities may be old woodpecker cavities or natural holes which the squirrel has enlarged. The tree dens are usually 6 inches wide, 14 - 16 in deep with a 2.9 by 3.7 in opening. In East Texas, 80% of these den trees had an average dbh of 30 cm (12 in) or more. If tree dens are not available, then leaf nests will be used; however, survival of a litter is usually 1.5 times higher in dens than leaf nests. Therefore, den trees should be protected so there is 2 - 6 per acre, but if these are scarce nest boxes can be used (MacClintock 1970, Allen 1982, Yarrow 1999).

Management

Two possible limiting factors for fox squirrels are the availability of winter food and tree dens. Therefore, forests should contain at least 40% mast producing tree species and rotations should be long enough to provide large, overmature trees in the mast producing age (which begins at 25 to 30 years of age for most oak species). Optimum mast production occurs in trees that are larger than 25.4 cm (10 in) dbh but to provide den trees the overstory trees should have an average dbh of 38.1 cm (15 in) or larger. Canopy closure should be kept between 20 to 60 %, since above 60% will reduce mast quality and quantity and below 20% will not provide suitable habitat. Fox squirrels prefer little understory vegetation; therefore, the shrub canopy closure should be kept less than 30%. Yarrow et al. (1999) suggest that to intensively manage for fox squirrel a forest should have at least a 60 - 100 year rotation, that prescribed burning should be used every 2 - 3 years, and thinning should be done ever 4 - 5 years. It is also suggested that all cuts should be less than 20 ac and 500 ft wide and that small selective cuts of ¼ to 1 acre are best (Allen 1982, Yarrow 1999).

Literature Cited

Allen, A.W. 1982. Habitat Suitability Index Models: Fox squirrel. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.18. 11 pp.

MacClintock, D. 1970. Squirrels of North America. Van Nostrand Reinhold Company, New York, New York, USA.

McCleery, R.A., R.R. LOPEZ, N. J. SILVY, and S.N. KAHLICK. 2007. Habitat Use of Fox Squirrels in an Urban Environment. JOURNAL OF WILDLIFE MANAGEMENT 71(4):1149–1157)

Weigl, P.D., M.A. Steele, L. J. Sherman, J.C. Ha, and T.L. Sharpe. 1989. The Ecology of the Fox Squirrel (*Sciurus niger*) in North Carolina: Implications for Survival in the Southeast. Tall Timbers Research Station Bulletin Number 24, Tallahassee, Florida, USA.

Yarrow, G. K. and D.T. Yarrow. 1999. Managing wildlife on private lands in Alabama and the Southeast. Alabama Wildlife Federation. Sweetwater Press, Birmingham, Alabama, USA.

Biological Services Program
and
Division of Ecological Services

FWS/OBS-82/10.18
JULY 1982

HABITAT SUITABILITY INDEX MODELS: FOX SQUIRREL

Fish and Wildlife Service

U.S. Department of the Interior

FWS/OBS-82/10.18
July 1982

HABITAT SUITABILITY INDEX MODELS: FOX SQUIRREL

by

Arthur W. Allen
Habitat Evaluation Procedures Group
Western Energy and Land Use Team
U.S. Fish and Wildlife Service
Drake Creekside Building One
2625 Redwing Road
Fort Collins, CO 80526

Western Energy and Land Use Team
Office of Biological Services
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

This report should be cited as:

Allen, A. W. 1982. Habitat suitability index models: fox squirrel. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.18. 11 pp.

PREFACE

This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for HSI models that follow. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model Section documents a habitat model and information pertinent to its application. The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The application information includes descriptions of the geographic ranges and seasonal application of the model, its current verification status, and a listing of model variables with recommended measurement techniques for each variable.

In essence, the model presented herein is a hypothesis of species-habitat relationships and not a statement of proven cause and effect relationships. Results of model performance tests, when available, are referenced. However, models that have demonstrated reliability in specific situations may prove unreliable in others. For this reason, feedback is encouraged from users of this model concerning improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning. Please send suggestions to:

Habitat Evaluation Procedures Group
Western Energy and Land Use Team
U.S. Fish and Wildlife Service
2625 Redwing Road
Ft. Collins, CO 80526

CONTENTS

ACKNOWLEDGMENTS

We gratefully acknowledge F. S. Barkalow and C. M. Nixon for their review of this habitat model. Word processing was provided by Carolyn Gulzow and Dora Ibarra. Cover illustration is by Larry Welo and originally appeared in Mount Rainier's Mammals.

FOX SQUIRREL (*Sciurus niger*)

HABITAT USE INFORMATION

General

The fox squirrel (*Sciurus niger*) is the largest of the North American tree squirrels. The species is widely distributed throughout eastern North American and has been introduced in many portions of the West (Wright 1979). Fox squirrels also have expanded their range westward through utilization of gallery forest habitats along major river drainages (Armstrong 1972; Wright 1979).

Food

Foods consumed by the fox squirrel include mast, tree buds, insects, tubers, bulbs, roots, bird eggs, and the seeds of spring fruiting trees (Lowery 1974). Winter foods are chiefly mast produced by oaks (*Quercus* spp.), hickories (*Carya* spp.), American beech (*Fagus grandifolia*), magnolias (*Magnoliaceae* spp.), gums (*Hamamelidaceae* spp.), and dogwoods (*Cornus* spp.). Agricultural crops such as corn, soybeans, oats, wheat, and fruit crops are also readily eaten by the fox squirrel (Brown and Yeager 1945).

Water

Succulent vegetation normally satisfies the moisture requirements of fox squirrels (Allen 1943; McConnell, pers. comm.). Water may be utilized when present; however, the lack of it is not a limiting habitat factor for the fox squirrel (U.S. Forest Service 1971).

Cover

Although fox squirrels inhabitat a wide variety of forest types, they are most abundant in open forest stands with little understory vegetation (Taylor 1974). Ideal habitat is comprised of small stands of large trees interspersed with agricultural lands. Optimal fox squirrel habitat in Michigan was small units of mature oak-hickory woodland connected by small wooded strips that served as travel lanes for squirrels (Allen 1943). Fox squirrel habitat in Ohio consisted of small, 2 to 121.4 ha (5 to 300 acres) farm woodlots (Baumgartner 1943).

Fox squirrels use leaf nests or tree cavities for shelter and litter rearing (Baumgartner 1943). However, they appear to use leaf nests more often than do gray squirrels (*S. carolinensis*) (Bakken 1952 cited by Taylor 1974; Donohoe and Beal 1972). Fox squirrels in Ohio utilized one to three shelters in their territory, at least one of which was a tree cavity (Donohoe and Beal 1972).

Hickories, white oak (*Quercus alba*), scarlet oak (*Q. coccinea*), and beech were the most frequently selected trees for construction of leaf nests in West Virginia, Ohio, and Illinois (Sanderson et al. 1980). The presence of grapevines (*Vitus* spp.) in a tree increased the likelihood of the trees being selected as a leaf nest site. Based on the average number of leaf nests constructed by a fox squirrel per year, it appears that four to six canopy-reaching grapevines per hectare (1.5 to 2.3/acre) provide an adequate number of leaf nest anchorages. Trees containing summer and winter leaf nests in Ohio averaged 37.8 cm (15.1 inches) dbh and 32.8 cm (13.1 inches) dbh, respectively (Baumgartner 1939).

Sassafras (*Sassafras albidum*), sugar maple (*Acer saccharum*), elm (*Ulmus* spp.), and beech contained a significantly greater proportion of suitable cavities than expected on the basis of their abundance in Illinois (Nixon et al. 1980). In contrast, walnut (*Juglans* spp.) and white oak contained significantly fewer cavities than expected. Den trees in Ohio had an average dbh of 53 cm (21.2 inches) and were an average of 50.9 m (58.6 yd) from the nearest woodland border (Baumgartner 1939). Eighty-eight percent of the den trees in eastern Texas had an average dbh of 30 cm (12 inches) or more (Baker 1944).

Reproduction

The reproductive requirements of the fox squirrel are assumed to be identical with cover requirements, as described above.

Interspersion

The home range of the fox squirrel in the Southeast is normally from 2 to 4 ha (5 to 10 acres) (U.S. Forest Service 1971). The mean home range size for male and female fox squirrels in Nebraska was 7.56 ha (18.7 acres) and 3.55 ha (8.8 acres), respectively (Adams 1976). A positive relationship exists between fox squirrel home range size and the area of the inhabited woodlot or forest stand (Adams 1976; Nixon pers. comm.). Adult female fox squirrels are more sedentary than are adult males or subadults (Nixon et al. 1980). Therefore, adult females are more susceptible to habitat changes that affect the availability of denning sites and food.

Special Considerations

Fox and gray squirrel ranges overlap throughout most of the eastern United States (Bakken 1952 cited by Taylor 1974). Coexistence of the two species is most evident in the western and northern portions of the ranges of both species (Bakken 1952 cited by Taylor 1974). Although the two species may inhabit the same general area, they tend to concentrate in slightly different habitats. Fox squirrels prefer open woodland habitats; gray squirrels typically inhabit large dense stands of hardwoods with dense understory cover

(Taylor 1974). Gray squirrels in Texas were more common in poorly drained lowland areas, whereas fox squirrels were more frequently associated with upland and well drained bottomland habitats (Goodrum 1938). Differences in habitat preference and foraging behavior are reflected in foods eaten. Fox squirrels in Missouri commonly inhabit open forests, forest edges, woodlots, and fence rows, where oak-hickory mast (52.2% of the annual diet) is supplemented with corn and other foods commonly associated with these habitats (Korschgen 1981). Gray squirrels occupy dense forests with nearly closed canopies and abundant ground cover and rely more heavily on oak-hickory mast (73.3% of annual diet) than do fox squirrels.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model appears to be most applicable in the ranges of the following subspecies of the fox squirrel: *S.n. rufiuenter*, *S.n. vulpinus*, *S.n. ludovicianus*, and *S.n. limitis* (Barkalow pers. comm.). Subspecies inhabiting the Outer Coastal Plain Forest and Southeastern Mixed Forest Provinces (Bailey 1980) appear to have sufficiently different habitat requirements to justify separate or modified habitat model(s).

Season. This model will produce HSI values for year-round habitat needs of the fox squirrel.

Cover types. This model is intended to evaluate fox squirrel habitat in the following cover types (terminology follows that of U.S. Fish and Wildlife Service 1981): Deciduous Forest (DF); Deciduous Tree Savanna (DTS); and Deciduous Forested Wetland (DFW).

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before an area will be occupied by a species. This information, as it pertains to the fox squirrel, was not found in the literature. The home range of the fox squirrel has been reported to range from 2 to 8 ha (5 to 20 acres). It is assumed that, if less than 2 ha (5 acres) of potentially suitable habitat is available, the HSI will equal 0.0.

Verification level. This model was reviewed by F.S. Barkalow, North Carolina State University, and C.M. Nixon, Illinois Institute of Natural Resources. Improvements suggested by these reviewers were incorporated into this model.

Model Description

Overview. This HSI model for the fox squirrel considers the quality of life requisites for the species in each cover type. Winter food and Cover/reproduction are the only life requisites considered in this model.

The following sections document the logic and assumptions used to translate habitat information for the fox squirrel into the variables and equations used in the HSI model. Specifically, these sections cover: (1) identification of variables used in the model; (2) definition and justification of the suitability levels of each variable; and (3) description of the assumed relationships between variables.

Figure 1 illustrates the relationships of habitat variables, life requisites, and cover types for the fox squirrel.

Food component. A wide variety of vegetative and animal materials may be consumed by the fox squirrel during the spring, summer, and fall. Winter foods are comprised almost wholly of hard mast and grain. It is assumed that the availability of winter food will be the most limiting component of the food requirements of the fox squirrel.

The winter food value for the fox squirrel is a function of hard mast production and, to a lesser extent, the availability of grain. Optimum food can be supplied by hard mast; however, grain availability may be extremely important during years of little or no mast production. It is assumed that the potential for optimum mast production will occur where a mix of white and red oaks, hickories, walnuts, and other mast producing trees comprise at least 40% of the total canopy cover of the forest or stand. Mast producing trees should equal or exceed 25.4 cm (10 inches) dbh to provide optimum mast production. As tree canopy closure increases above 60%, mast quality and quantity is reduced due to suppression and shading of tree crowns by adjacent trees. It also is assumed that grain within 200 m (220 yds) of a forest or stand will have optimal value as a supplement to the winter diet of the fox squirrel. Available grain in excess of 200 m (220 yds) will have a lower potential as a supplement. The winter diet of fox squirrels will never be completely limited by the absence of a source of grain. It is assumed that potential mast production is at least three times as important in supplying winter food for the fox squirrel as is the availability of grain.

Cover and Reproductive Component. Fox squirrels inhabitat a variety of forest types. However, they are most abundant in open forest stands with sparse understory vegetation.

Although fox squirrels commonly utilize leaf nests for shelter and litter rearing, the presence of tree cavities will increase the quality of the habitat. It is assumed that the physical structure of a forest stand is an indication of the availability of tree cavities. Forest stands dominated by mature to overmature trees are assumed to provide cavities and a sufficient number of sites for leaf nests to meet the cover requirements of the species. Overstory trees which have an average dbh of 38.1 cm (15 inches) or larger are assumed to provide adequate cover and reproductive habitat. Optimum tree canopy closure is assumed to range from 20 to 60%. A canopy closure of less than 20% will indicate less suitable habitat, as will tree density exceeding 60%. Understory vegetation comprised of shrubs may decrease habitat quality for the fox squirrel. Optimum conditions are assumed to occur when the shrub crown closure is 30% or less. Habitat quality will decrease as the shrub density increases above 30%, regardless of tree canopy closure and overstory size. A shrub density of 100% is assumed to be indicative of habitat with no suitability for fox squirrels.

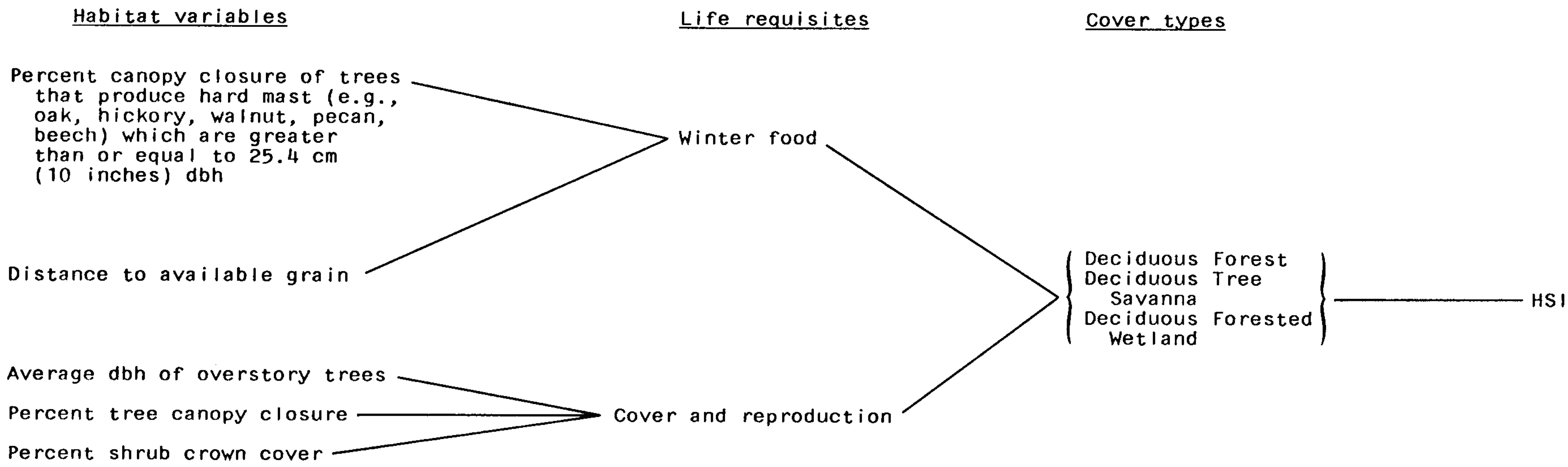
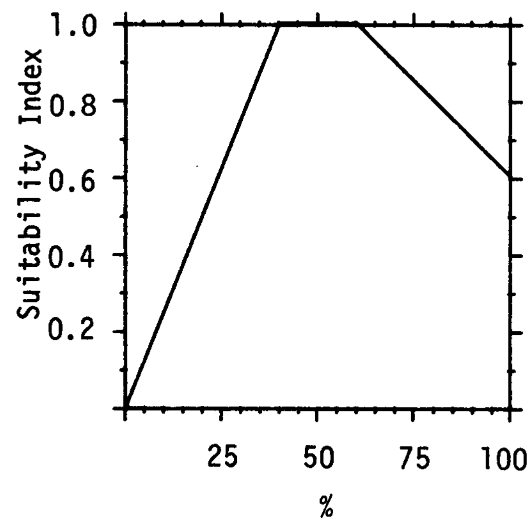
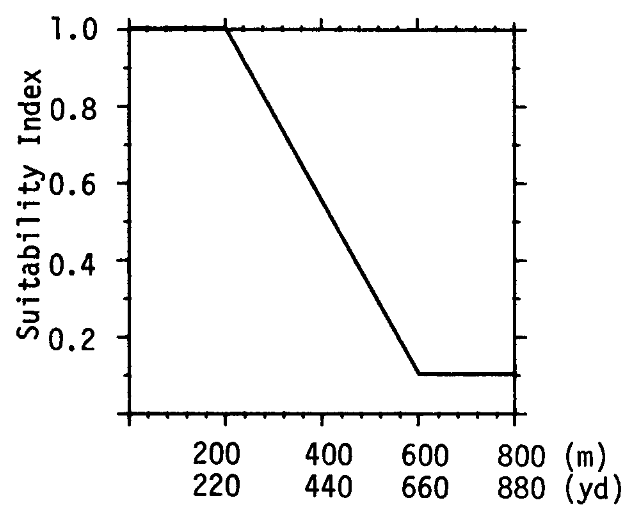


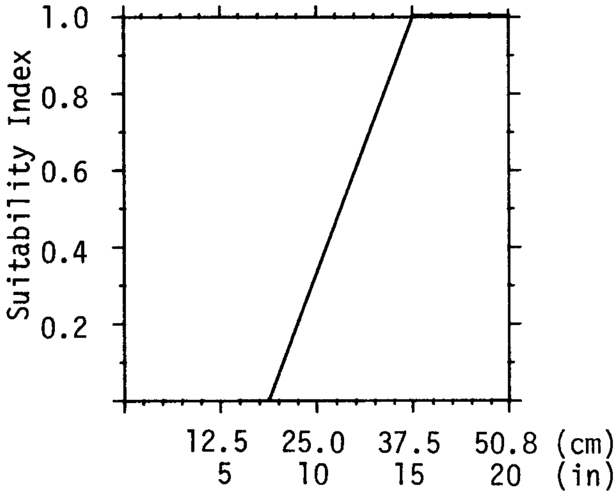
Figure 1. The relationship of habitat variables, life requisites, and cover types to the HSI for the fox squirrel.

Model Relationships

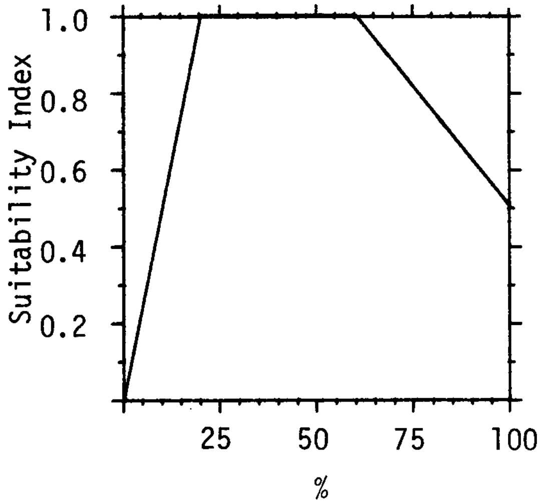
Suitability Index (SI) curves for habitat variables. This section contains suitability index graphs that illustrate the habitat relationships described in the previous section.

Cover type	Variable		
DF,DTS, DFW	V_1	Percent canopy closure of trees that produce hard mast (e.g., oak, hickory, walnut, pecan, beech) ≥ 25.4 cm (10 inches) dbh.	
DF,DTS,DFW	V_2	Distance to available grain.	

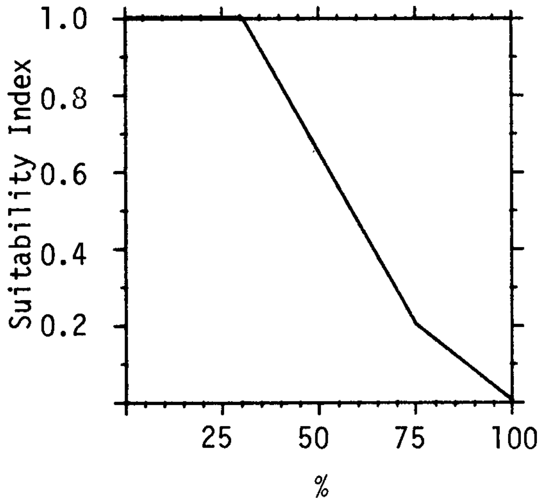
DF, DTS, DFW — V_3 — Average dbh of overstory trees.



DF, DTS, DFW — V_4 — Percent tree canopy closure.



DF, DTS, DFW — V_5 — Percent shrub crown cover.



Equations. In order to obtain life requisite values for the fox squirrel, the SI values for appropriate variables must be combined with the use of equations. A discussion and explanation of the assumed relationships between variables was included under Model Description. The suggested equations for obtaining the food and cover/reproduction values are presented in Figure 2.

Life requisite	Cover type	Equations
Winter food	DF,DTS,DFW	$\frac{3V_1 + V_2}{3}$
Cover/reproduction	DF,DTS,DFW	$(V_3 \times V_4 \times V_5)^{1/3}$

Figure 2. Equations for determining life requisite values by cover type for the fox squirrel.

HSI determination. A HSI value for a single cover type species is based on the limiting factor concept and equals the lowest life requisite value.

Application of the Model

Definitions of variables and suggested field measurement techniques (Hays et al. 1981) are presented in Figure 3.

Variable [definition]		Cover types	Suggested technique
V_1	Percent canopy closure of trees that produce hard mast (e.g., oak, hickory, walnut, pecan, beech) ≥ 25.4 cm (10 inches) dbh [the percent of the ground that is shaded by the vertical projection of the canopies of trees which produce a hard shelled fruit and have a dbh of at least 25.4 cm (10 inches)].	DF,DTS,DFW	Calculated area of plant using crown diameter on strip quadrat

Figure 3. Definitions of variables and suggested measurement techniques.

Variable [definition]		Cover types	Suggested technique
V_2	Distance to available grain [the linear distance from sample point to grain crops that are available to fox squirrels. Grain may be available as standing crop, waste, or stored grain].	DF,DTS,DFW	On site inspection, remote sensing
V_3	Average dbh of overstory trees [the average diameter at breast height (1.4 m/4.5 ft) of those trees which are ≥ 80 percent of the height of the tallest tree in the stand.	DF,DTS,DFW	Cruise for tallest tree in stand. Sample with optical range finder and Biltmore stick on strip quadrat
V_4	Percent tree canopy closure [the percent of the ground surface shaded by a vertical projection of the canopies of all woody vegetation greater than 5.0 m (16.5 ft) tall].	DF,DTS,DFW	Line intercept, remote sensing
V_5	Percent shrub crown cover [the percent of the ground shaded by a vertical projection of the canopies of woody vegetation less than 5 m (16.5 ft) tall].	DF,DTS,DFW	Line intercept

Figure 3. (concluded)

SOURCES OF OTHER MODELS

Numerical habitat models by Flood et al. (1977) and Hallett (1980) were located in the literature.

REFERENCES

Adams, C. E. 1976. Measurements and characteristics of fox squirrel, Sciurus niger rufiventer, home ranges. Am. Midl. Nat. 95(1):211-215.

Allen, D. L. 1943. Michigan fox squirrel management. Michigan Dept. of Conserv., Game Div. Publ. 100. 404 pp.

Armstrong, D. M. 1972. Distribution of mammals in Colorado. University of Kansas. Lawrence, Kansas. 415 pp.

Bailey, R. G. 1980. Description of the ecoregions of the United States. U.S.D.A. For. Serv. Misc. Publ. 1391. 77 pp.

Baker, R. H. 1944. An ecological study of tree squirrels in eastern Texas. J. Mammal. 25(1):8-24.

Bakken, A. 1952. Interrelatonships of Sciurus carolinensis (Gmelin) and Sciurus niger (Linneaus) in mixed populations. Ph.D. Thesis., Univ. Wisc., ________. 188 pp. Cited by Taylor 1974.

Barkalow, F. S., Jr. Personal communication. Zoology Dept., North Carolina State Univ., Raleigh.

Baumgartner, L. L. 1939. Fox squirrel dens. J. Mammal. 20(4):456-465.

____________. 1943. Fox squirrels in Ohio. J. Wildl. Manage. 7(2):193-202.

Brown, L. G., and L. E. Yeager. 1945. Fox and gray squirrels in Illinois. Illinois Nat. Hist. Surv. Bull. 23(5):449-532.

Donohoe, R. W., and R. O. Beal. 1972. Squirrel behavior determined by radio telemetry. Ohio Dept. Nat. Resour., Fish and Wildl. Rep. 2. 20 pp.

Flood, B. S., M. E. Sangster, R. D. Sparrowe, and T. S. Baskett. 1977. A handbook for habitat evaluation procedures. U.S.D.I. Fish Wildl. Serv. Res. Publ. 132. Washington, D.C. 77 pp.

Goodrum, P. 1938. Squirrel management in eastern Texas. Trans. N. Am. Wildl. Conf. 3:670-676.

Hays, R. L., C. Summers, and W. Seitz. 1981. Estimating wildlife habitat variables. U.S.D.I. Fish and Wildl. Serv. FWS/OBS-81/77. 111 pp.

Hallett, D. L. 1980. Fox squirrel (Sciurus niger). Pages 42-48 in T. S. Baskett, D. A. Darrow, D. L. Hallett, M. J. Armbruster, J. A. Ellis, B. F. Sparrowe, and P. A. Koste, eds. A handbook for terrestrial habitat evaluation in central Missouri. U.S.D.I. Fish and Wildl. Serv. Res. Publ. 133. Washington, D. C. 155 pp.

Korschgen, L. J. 1981. Foods of fox and gray squirrels in Missouri. J. Wildl. Manage. 45(1):260-266.

Lowery, G. H., Jr. 1974. The mammals of Louisiana and its adjacent waters. Louisiana State Univ. Press, Baton Rouge. 565 pp.

MacClintock, D. 1970. Squirrels of North America. Van Nostrand Reinhold Co., New York. 184 pp.

McConnell, C. A. Personal communication (letter dated 21 November 1978), Wildlife Management Institute, Washington, D.C.

Nixon, C. M. Personal communication (letter dated 2 October 1981). Illinois Inst. Nat. Resour., Champaign, Ill.

Nixon, C. M., S. P. Havera, and L. P. Hansen. 1980. Initial response of squirrels to forest changes associated with selection cutting. Wildl. Soc. Bull. 8(4):298-306.

Sanderson, H. R., C. M. Nixon, R. W. Donohoe, and L. P. Hansen. 1980. Grapevines - an important component of gray and fox squirrel habitat. Wildl. Soc. Bull. 8(4):307-310.

Taylor, G. J. 1974. Present status and habitat survey of the Delmarva fox squirrel (Sciurus niger cinereus) with a discussion of reasons for its decline. Proc. Southeastern Assoc. Game and Fish Commissioners 27:278-289.

U.S. Fish and Wildlife Service. 1981. Standards for the development of habitat suitability index models. 103 ESM. U.S.D.I. Fish Wildl. Serv., Div. Ecol. Serv. n.p.

U.S. Forest Service. 1971. Wildlife habitat management handbook. Southern Region. U.S.D.A. For. Serv. FSH 2609.23. n.p.

Wright, G. M. 1979. Range extension of the fox squirrel in southeastern Washingtqn and into adjacent Idaho. Murrelet 60(2):73-75.

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. FWS/OBS-82/10.18	2.	3. Recipient's Accession No.

4. Title and Subtitle

Habitat Suitability Index Models: Fox Squirrel

5. Report Date July 1982

6.

7. Author(s) Arthur W. Allen

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

Habitat Evaluation Procedures Group
Western Energy and Land Use Team
U.S. Fish and Wildlife Service
Drake Creekside Building One
2625 Redwing Road
Fort Collins, Colorado 80526

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C)
(G)

12. Sponsoring Organization Name and Address

Western Energy and Land Use Team
Office of Biological Services
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

Habitat preferences and species characteristics of the fox squirrel (Sciurus niger) are described in this publication. It is one of a series of Habitat Suitability Index (HSI) models and was developed through an analysis of available scientific data on the species-habitat requirements of the fox squirrel. Habitat use information is presented in a review of the literature, followed by the development of a HSI model. The model is presented in three formats: graphic, word, and mathematical. Suitability index graphs quantify the species-habitat relationship. These data are then synthesized into a model which is designed to provide information for use in impact assessment and habitat management activities.

17. Document Analysis a. Descriptors

Wildlife
Animal behavior
Animal ecology
Habitability
Mathematical models
Mammals
Squirrels

b. Identifiers/Open-Ended Terms

Fox squirrel
Sciurus niger
Habitat suitability
Habitat preference
Habitat management
Habitat suitability index models
Habitat requirements
Species-habitat relationships
Impact assessment

c. COSATI Field/Group

18. Availability Statement

Unlimited

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page) UNCLASSIFIED

21. No. of Pages ii - v + 11 pp

22. Price

(See ANSI-Z39.18)

See Instructions on Reverse

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

☆ U.S. Government Printing Office 1982 - 580-611/411 Reg. 8

Great Trinity Forest Management Plan

Wildlife Management

Hairy Woodpecker

(Picoides villosus)

Hairy woodpecker
(*Picoides villosus*)

The hairy woodpecker is a nonmigratory bird that is among the most widespread and familiar birds of North America. Predators include coopers hawk (*Accipiter cooperii*), barred owl (*Strix varia*), sharp-skinned hawk (*Accipiter striatus*), Northern goshawk (*Accipiter gentilis*), great horned owl (*Bubo virginianus*) and rat snake (*Elaphe* spp). Predators that may attack young include eastern screech owl (*Megascops asio*), house sparrow (*Passer domesticus*), European starling (*Sturnus vulgaris*), red bellied woodpecker (*Melanerpes carolinus*), rat snake and raccoons (*Procyon lotor*). (Sousa 1987, Jackson et al. 2002)

Food

This species of woodpecker forages on live and dead trees by gleaning or excavating, but they may also forage on the ground or on down timber. They mostly (more than 75%) feed on insects such as beetle larvae, ants, caterpillars and adult beetles but they also eat fruit and mast. (Sousa 1987, Jackson et al. 2002)

Water

Its water needs are unknown (Sousa 1987)

Habitat

This species uses a wide variety of habitats, from residential to wooded riparian areas, as long as mature trees are present for roosting, winter cover, nesting and rearing young. Territory size of this species is influenced by habitat quality; therefore, it is very variable and can range from 0.6 to 15 ha (1.5 to 37.1 ac). However, to support a viable breeding population it is suggesting that at least 4 ha is needed even though other sources suggest that at least 12 ha (29.7 ac) is needed. (Sousa 1987, Jackson et al. 2002)

Reproduction

This is a primary cavity nester which prefers live trees with heart rot but will nest in dead trees or stubs. The optimal suggested diameter for nest trees is 25 - 35 cm (9.8 - 13.8 in) and no less than 25 cm (9.8 in). The suggested optimal height of cavities is 6 - 12 m (19 - 39.4 ft) and no less than 4.6 m (15.1 ft). Despite these suggested ranges, this species will use a variety of habitats as long as there are trees present of adequate size and decay. In fact, they have been reported nesting in a wide variety of successional stages, even in stumps in a forest regeneration area. One threat to hairy woodpecker nests is competition with other cavity nesting species such as flying squirrels and sapsuckers.
(Sousa 1987, Jackson et al. 2002)

Management

To provide suitable reproductive habitat for this species, Sousa (1987) states that there should be more than 5 snags/ha (more than 2 snags/acre) and the mean dbh of the overstory trees should be more than 40 cm (more than 16 in). To provide suitable cover and food habitat, the mean dbh of the overstory trees should by greater than 25 cm (9.8 in) and there should be 85 - 90% canopy cover. This species has been known to use younger forests and moderate canopy cover; however, that habitat is considered less than optimal. Experts also found that the more pine in the overstory degraded the habitat, so the overstory pine canopy closure should be less than 10%. To achieve these mature forests described above, tracts of hardwood or mixed forest should be protected and on a long rotation. Also, at least 40 m (131.2 ft) wide habitat corridors and streamside management zones should be maintained on a property. (Sousa 1987, Jackson et al. 2002)

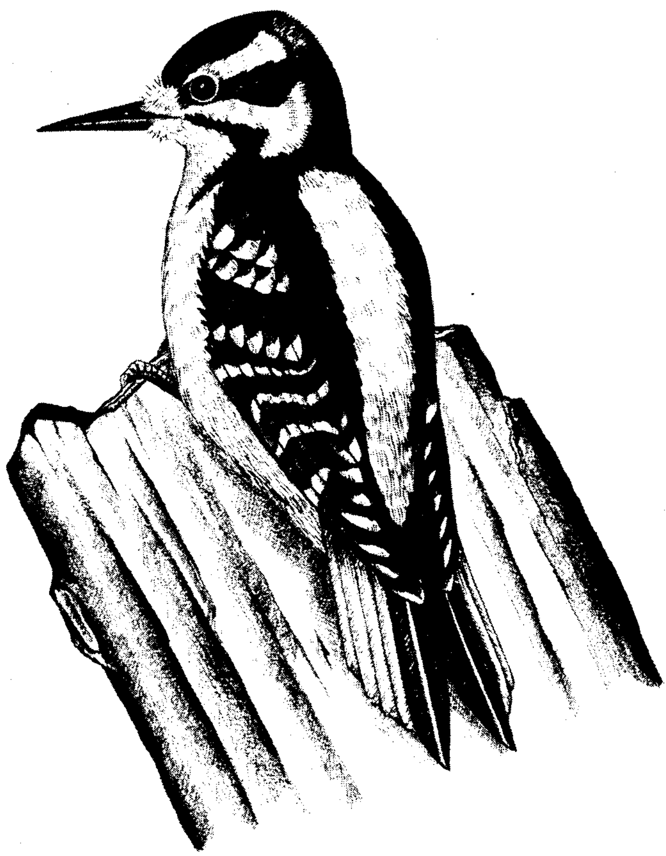
Literature Cited

Jackson, J. A., H. R. Ouellet, and B. J. S. Jackson. 2002. Hairy Woodpecker (*Picoides villosus*). *In* The Birds of North America, No. 702 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Sousa, P.J. 1987. Habitat Suitability Index Models: Hairy Woodpecker. U.S. Fish and Wildlife Service, Biological Report 82(10.146). 19 pp.

BIOLOGICAL REPORT 82(10.146)
SEPTEMBER 1987

HABITAT SUITABILITY INDEX MODELS: HAIRY WOODPECKER



Fish and Wildlife Service

U.S. Department of the Interior

Biological Report 82(10.146)
September 1987

HABITAT SUITABILITY INDEX MODELS: HAIRY WOODPECKER

by

Patrick J. Sousa
U.S. Fish and Wildlife Service
National Ecology Center
Creekside One Building
2627 Redwing Road
Fort Collins, CO 80526-2899

U.S. Department of the Interior
Fish and Wildlife Service
Research and Development
Washington, DC 20240

Suggested citation:

Sousa, P.J. 1987. Habitat suitability index models: hairy woodpecker. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.146). 19 pp.

PREFACE

This document is part of the Habitat Suitability Index (HSI) model series [Biological Report 82(10)], which provides habitat information useful for impact assessment and habitat management. Several types of habitat information are provided. The Habitat Use Information section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. This information provides the foundation for the HSI model and may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model section documents the habitat model and includes information pertinent to its application. The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The HSI Model section includes information about the geographic range and seasonal application of the model, its current verification status, and a list of the model variables with recommended measurement techniques for each variable.

The model is a formalized synthesis of biological and habitat information published in the scientific literature and may include unpublished information reflecting the opinions of identified experts. Habitat information about wildlife species frequently is represented by scattered data sets collected during different seasons and years and from different sites throughout the range of a species. The model presents this broad data base in a formal, logical, and simplified manner. The assumptions necessary for organizing and synthesizing the species-habitat information into the model are discussed. The model should be regarded as a hypothesis of species-habitat relationships and not as a statement of proven cause and effect relationships. The model may have merit in planning wildlife habitat research studies about a species, as well as in providing an estimate of the relative suitability of habitat for that species. User feedback concerning model improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning are encouraged. Please send suggestions to:

Resource Evaluation and Modeling Section
U.S. Fish and Wildlife Service
National Ecology Center
2627 Redwing Road
Ft. Collins, CO 80526-2899

CONTENTS

ACKNOWLEDGMENTS

A field validation of an earlier version of the HSI model for the hairy woodpecker was conducted under the direction of Ms. L. Jean O'Neil, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. The field validation was based on habitat evaluation by the following individuals:

Dr. F.J. Alsop, III, East Tennessee State University, Johnson City

Dr. C.E. Bock, University of Colorado, Boulder

Dr. R.N. Conner, U.S. Forest Service, Nacogdoches, TX

Dr. J.A. Jackson, Box Z, Mississippi State, MS

Dr. F.C. James, Florida State University, Tallahassee

Dr. B.J. Schardien Jackson, Mississippi State, MS

Mr. J. Teaford and Dr. T. Roberts, Waterways Experiment Station, and Dr. J. Wakeley, Pennsylvania State University, assisted in the study design, data collection, data analysis, and model modification. The field validation resulted in several improvements in the model. The efforts of all of those involved in the field validation are very much appreciated.

Earlier drafts of the model were reviewed by Dr. R.N. Conner and Dr. C.E. Bock. Their review comments led to significant improvements in the model and are appreciated.

Word processing of this document was provided by C. Gulzow, D. Ibarra, P. Gillis, and E. Barstow. The cover was illustrated by J. Shoemaker.

HAIRY WOODPECKER (*Picoides villosus*)

HABITAT USE INFORMATION

General

The hairy woodpecker (*Picoides villosus*) breeds and winters throughout most of North America (American Ornithologists' Union 1983). The species is a primary cavity nester in "deciduous or coniferous forest, well-wooded towns and parks, and open situations with scattered trees ..." (American Ornithologists' Union 1983:391).

Food

Animal matter, such as beetle larvae (Coleoptera), ants (Hymenoptera), caterpillars (Lepidoptera), and adult beetles, accounted for 78% of the hairy woodpecker's annual diet, based on 382 stomachs collected throughout North America (Beal 1911). The diet is supplemented by fruit and mast (Beal 1911; Hardin and Evans 1977). Hairy woodpeckers forage extensively for seeds in winter (Jackman 1975); in Colorado, they foraged extensively during the non-reproductive season on the seeds of ponderosa pine (*Pinus ponderosa*) (Stallcup 1966). Hairy woodpeckers may concentrate in areas of insect outbreaks in response to the increased food source (Koplin 1967; Massey and Wygant 1973). The hairy woodpecker was considered to be a primary predator of the Southern pine beetle (*Dendroctonus frontalis*) in east Texas (Kroll and Fleet 1979).

Hairy woodpeckers are considered opportunistic foragers (Raphael and White 1984); they forage on a variety of substrates, including tree trunks, stumps, exposed roots (Lawrence 1966), snags, downed logs, the ground (Mannan et al. 1980), and logging debris in recent clearcuts (Conner and Crawford 1974). In California, hairy woodpeckers foraged on snags 51% of the time and on live trees 47% of the time (Raphael and White 1984). During winter, hairy woodpeckers in Virginia foraged most often on dead trees or dead parts of live trees (Conner 1980). Hairy woodpeckers in New York exhibited a sexual difference in the selection of winter foraging sites; males foraged on dead trees significantly more often than females, and females foraged significantly more often on live trees (Kisiel 1972). Both sexes used a variety of tree species for foraging sites. A variety of tree species was also used for foraging by hairy woodpeckers in Sierra Nevada forests (Raphael and White 1984). Snags used for foraging in Douglas-fir (*Pseudotsuga menziesii*) forests in Oregon averaged 61 cm dbh and ranged from 13 to 173 cm dbh (Mannan 1977). The average foraging height of hairy woodpeckers in Iowa was 8.8±1.55 m, and the average diameter of limbs used for foraging was 6.52±1.04 cm (Gamboa and Brown 1976). Hairy woodpeckers in New York typically foraged on limbs 5 to 10 cm in diameter (Kisiel 1972).

Hairy woodpeckers in southwestern Virginia foraged in "... habitats with relatively dense vegetation near the ground" (Conner 1980:121) in comparison to foraging habitat selected by other species of woodpeckers, especially the downy woodpecker (P. pubescens).

Water

No specific information on water requirements of the hairy woodpecker was found in the literature.

Cover

Hairy woodpeckers inhabit a wide variety of forest cover types. For example, they inhabit Douglas-fir forests (Mannan et al. 1980), ponderosa pine forests (Diem and Zeveloff 1980), pinyon-juniper (Pinus edulis - Juniperus spp.) woodlands (Balda and Masters 1980), eastern deciduous forests (Conner et al. 1975), and riparian communities (Stauffer and Best 1980). Winter population densities of hairy woodpeckers in Illinois were positively correlated with the number of trees >56 cm dbh and with a diversity of genera and species of large trees (Graber et al. 1977). Hairy woodpeckers in Oregon use the shrub/sapling (8 to 15 yr) and second-growth (16 to 40 yr) stages of Douglas-fir forests, but they do not nest in these younger stages (Meslow and Wight 1975). Jackman (1975) stated that hairy woodpeckers inhabit second-growth, partially thinned, and other altered forest types; however, hairy woodpeckers were reported more frequently (95% of 40 breeding bird censuses) in mature undisturbed habitats in the northern hardwoods region than in disturbed and successional habitats (43% of 30 censuses) (Noon et al. 1979).

Hairy woodpeckers use tree cavities for roosting and winter cover, as well as for nesting and rearing young (Thomas et al. 1979), and they will excavate new cavities in the fall to be used for roosting (Jackman 1975).

Reproduction

The hairy woodpecker is a primary cavity nester that is able to adapt to a wide variety of habitats (Kilham 1968). In the Pacific Northwest, hairy woodpeckers require standing dead trees and live trees with rotted heartwood (Jackman 1975). Similarly, hairy woodpeckers in Virginia exhibited a definite preference for trees with heartrot (Conner et al. 1975; Conner et al. 1976). Thomas et al. (1979), however, listed the hairy woodpecker as a species that usually excavates in sound wood. Runde and Capen (1987) found that the amount of sound wood varied widely (based on a visual estimate) in live trees used for nesting by hairy woodpeckers; 11 of 21 nests were in live trees. A possible exception to the apparently general use of live or dead trees for nest sites is that hairy woodpeckers do not nest in Engelmann spruce (Picea engelmannii) forests in the Pacific Northwest (Jackman 1975). Haapanen (1965 cited by Smith 1980:264) found that "of all the woodpeckers found in spruce-fir forests, apparently only the Northern 3-toed Woodpecker [Picoides tridactylus] is capable of making holes in the dense wood of living spruce trees." R.N. Conner (U.S. Forest Service, Nacogdoches, TX; letter dated February 19, 1986) suggests, however, that Engelmann spruce and other North American spruces are relatively soft-wooded trees (compared to oaks) that can be easily excavated by some species of woodpeckers. He suggests that the lack of use may be due to the absence of heartwood decay or to resin produced by spruce rather than to the density of the spruce wood. Whatever the reason for the observed lack of use, Conner believes that insufficient data exist to categorically classify live spruces as unsuitable for excavation by hairy woodpeckers.

Preferred nesting areas of hairy woodpeckers in east Tennessee were characterized by a large number of trees >23 cm dbh and associated high canopy biomass (Anderson and Shugart 1974). Hairy woodpeckers in Virginia apparently preferred areas with high stem density, but nested in areas with a wide range of basal areas, canopy heights, stem densities, and distances from cleared areas (Conner and Adkisson 1977). In northwestern Washington, hairy woodpecker nests were found in a variety of successional stages, though most were in, or at the edge of, old-growth forests (Zarnowitz and Manuwal 1985). Hairy woodpeckers in Washington are found in open rather than dense stands of timber (Larrison and Sonnenberg 1968), and in California's Sierra Nevada they prefer forests of low to moderate canopy closure (<70%) (Verner 1980). Both understocked and fully stocked stands in Virginia were suitable nesting areas as long as decayed trees were present (Conner et al. 1975). Hairy woodpeckers have even been reported nesting in the grass-forb stage of mixed coniferous forest regeneration by using stumps <1.5 m tall (Verner 1980).

Hairy woodpeckers require trees with a minimum dbh of 25 cm and a minimum height of 4.6 m for nesting (Thomas et al. 1979). Raphael and White (1984:24) found that "...diameter was the tree characteristic most closely correlated with nesting use" for 17 cavity-nesting birds. Conner and Adkisson (1976) found that canopy height had a greater influence on distinguishing between "possible nesting habitat" and "not nesting habitat" than did either basal area or stem density. In Vermont, no significant difference in mean tree height was detected between nest trees and adjacent non-nest trees (Runde and Capen 1987). Diameter at breast height (dbh) and diameter at nest height (dnh) were significantly greater for nest trees than non-nest trees ($\bar{x}$ dbh:27.1±1.3 cm vs. 23.9±0.7 cm, $P<0.05$; $\bar{x}$ dnh:22.4±1.1 cm vs. 13.2±9.6 cm, $P<0.01$). The probable optimum diameter range for hairy woodpecker nest trees is 25 to 35 cm dbh, and the probable optimum height range for nest trees is 6 to 12 m (Evans and Conner 1979). In Douglas-fir forests, however, hairy woodpeckers nest in older second-growth (41 to 120 yr) and mature (120+ yr) forests (Meslow and Wight 1975); these age classes are presumably taller than the optimum range suggested by Evans and Conner (1979). The average height of eight trees used for nesting in a Colorado aspen forest was 18 m, and ranged from about 11 to 21.3 m (Scott et al. 1980). Ten trees used for nesting in Virginia averaged 13.0 m tall and ranged from 4 to 26.5 m (Conner et al. 1975). The diameter of the tree at the cavity level in these 10 trees averaged 25.2 cm and ranged from 20 to 46 cm. In California, 19 nest trees averaged 13.7 m tall with an average diameter at the cavity level of 36.3±2.09 cm (Raphael and White 1984). Table 1 summarizes tree condition, nest heights, and nest tree diameter from several studies.

Table 1. Characteristics of nest sites selected by hairy woodpeckers in several study areas.

Source	Number of nests (n)	Tree condition Dead	Tree condition Live	Average nest height (range)	Average nest tree dbh (range)
Lawrence (1966) (NH)	11 (n=7 for dbh)	1	10	10.5 m (4.5-14 m) 34.9 ft (15-45 ft)	28 cm (25.4-34.8 cm) 11.1 inches (10-13.7 inches)
Conner et al. (1975) (VA)	10	5	5[a]	8.8 m (2.4-19.8 m) 28.9 ft (7.9-65 ft)	40.6 cm (20-64 cm) 16 inches (7.9-25.2 inches)
Jackman (1975) (OR)	33	?	?	7.6 m (5-10 m) 24.9 ft (16.4-32.8 ft)	?
Graber et al. (1977) (IL)	17	6	11[b]	4.6-10.7 m 15-35 ft	?
Mannan (1977) (OR)	7	?	?	18.2 m (7.9-41.8 m) 59.4 ft (25.9-137.1 ft)	92 cm (48-172 cm) 36.2 inches (18.9-67.8 inches)
Scott et al. (1980) (CO)	8	2	6	10 m (6.7-15.2 m) 33 ft (22-50 ft)	38 cm (25.4-58.4 cm) 15 inches (10-23 inches)
Raphael and White (1984) (CA)	19	16	3[c]	4.9±0.69 m 16.1±2.26 ft	43.8 cm 17.2 inches
Zarnowitz and Manuwal (1985) (WA)	16	16[d]	-	13±12 m 42.6±39.4 ft	41±13 cm 16.1±5.1 inches
Runde and Capen (1987) (VT)	21	10	11[e]	17.5±1.2 m 57.4±3.9 ft	27.1±1.3 cm 10.7±0.5 inches

[a] Four of the five nests in live trees were located in dead portions of the trees; the fifth was located in a totally live oak tree with a decayed heartwood (Conner, unpubl.).

[b] About one-half of these nests were located in dead portions of the trees.

[c] Located in dead portions of live trees.

[d] All nests located in broken-top trees.

[e] All 11 cavities were drilled through live wood.

Hairy woodpeckers will excavate in both hard and soft snags (Evans and Conner 1979); however, hairy woodpecker breeding densities were significantly positively correlated ($P \leq 0.01$) with soft snags in Iowa riparian forests (Stauffer and Best 1980). The hairy woodpecker was categorized as a soft snag excavator in Sierra Nevada forests (Raphael and White 1984). Evans and Conner (1979) estimated that 200 snags were necessary in order to support the maximum population of hairy woodpeckers on 40 ha of forest. Their estimate was based on a minimum annual need of four cavities per pair, and an assumption that only 10% of the available snags would be suitable for use. Snag density requirements decreased in direct proportion to the percentage of maximum population desired; e.g., 160 snags are required to support 80% of the maximum population, and 100 snags would support 50% of the maximum population. A similar estimate for the Blue Mountains of Oregon and Washington was that 180 snags/40 ha are necessary to support maximum populations of hairy woodpeckers (Thomas et al. 1979). Raphael and White (1984) distinguished between hard and soft snags in estimating the density of snags required to support the maximum density of hairy woodpeckers. They assumed a maximum density of 16 pairs/40 ha, an annual rate of excavation of 4 cavities/pair, and a reserve of 3 suitable cavities per pair to arrive at an estimate of 192 suitable snags/40 ha to support the maximum density. They further estimated that 4 hard snags are required to produce 1 soft snag, resulting in an estimate of 768 "hard snag equivalents" (Raphael and White 1984:56) per 40 ha. Although low numbers of snags can, in theory, support low-density woodpecker populations, enough snags to support 40% of the maximum population was assumed to be the minimum that will support a self-sustaining population of hairy woodpeckers in the Pacific Northwest (Bull 1978).

Interspersion and Composition

Territory size in a mature bottomland forest in Illinois averaged 1.1 ha and ranged from 0.6 to 1.5 ha (Calef 1953 cited by Graber et al. 1977). Reported territory size of hairy woodpeckers in the Blue Mountains of Washington and Oregon averaged 2.4 to 3.6 ha (Thomas et al. 1979). Evans and Conner (1979), however, reported an average territory size of 8 ha based on available literature, whereas territories reported for two hairy woodpeckers in Kansas were 9 and 15 ha (Fitch 1958). Home range and territory size are strongly influenced by habitat quality and, therefore, can be quite variable (Conner, unpubl.).

In a study of bird use of various sized forested habitats in New Jersey, hairy woodpeckers did not occur in areas of <2 ha (Galli et al. 1976). A minimum width of riparian forest necessary to support breeding populations of hairy woodpeckers in Iowa was 40 m (Stauffer and Best 1980). Robbins (1979) compared frequency of occurrence of hairy woodpeckers at Breeding Bird Survey stops in Maryland to the amount of contiguous forested area. The greatest decrease in frequency of occurrence was recorded at 4 ha of contiguous forested habitat, and Robbins (1979) proposed this value as a preliminary estimate of the minimum area necessary to support a viable breeding population of hairy woodpeckers. Conner (unpubl.), however, believes that 4 ha may represent the minimal area that hairy woodpeckers will use, but that such a small area could not support a viable breeding population, which he considers to be a minimum of 250 pairs. He suggested a minimum habitat area of 12 ha to support several breeding pairs of hairy woodpeckers (R.N. Conner, U.S. Forest Service, Nacogdoches, TX; letter dated December 1, 1981).

Although the hairy woodpecker is considered a resident species throughout its range, altitudinal migrations between mountainous areas and lower elevations do occur (Bailey and Niedrach 1965).

Special Considerations

The hairy woodpecker has been classed as a "tolerant species" to habitat alteration in Iowa (Stauffer and Best 1980), but also has been suggested as a sensitive environmental indicator of the ponderosa pine community (Diem and Zeveloff 1980).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model was developed for application within forested habitat throughout the entire range of the hairy woodpecker. Use of the model differs, however, between forests in the eastern United States and the western United States. The differences in application are described in the model.

Season. This model was developed to evaluate the year-round habitat of the hairy woodpecker.

Cover types. This model was developed to evaluate habitat in the following forested cover types: Deciduous Forest (DF), Evergreen Forest (EF), Deciduous Forested Wetland (DFW), and Evergreen Forested Wetland (EFW) (terminology follows U.S. Fish and Wildlife Service 1981).

Minimum habitat area. A minimum of 4 ha of forested habitat has been estimated to be necessary to support a viable breeding population of hairy woodpeckers (Robbins 1979), although Conner (unpubl.) believes that such a small area may represent the minimum needed to support one pair rather than a viable breeding population. Conner (unpubl.) suggested 12 ha as a reasonable estimate of the area needed to support several pairs of hairy woodpeckers. Additionally, forested riparian zones should be at least 40 m wide to be considered as potential breeding habitat for hairy woodpeckers (Stauffer and Best 1980).

Verification level. An earlier draft of the HSI model for the hairy woodpecker was used in a field evaluation of model outputs compared to expert opinion (O'Neil et al. 1988). The following species experts participated in the field evaluation:

Dr. F.J. Alsop, III, East Tennessee State University, Johnson City

Dr. C.E. Bock, University of Colorado, Boulder

Dr. R.N. Conner, U.S. Forest Service, Nacogdoches, TX

Dr. J.A. Jackson, Box Z, Mississippi State, MS

Dr. F.C. James, Florida State University, Tallahassee

Dr. B.J. Schardien Jackson, Mississippi State, MS

Initial results indicated that outputs from the earlier model were poorly correlated ($r=0.07$, $P>0.50$) with habitat ratings by experts for 40 sites in eastern Tennessee (O'Neil et al. 1988). Important habitat criteria identified by the experts were used to modify the model in an attempt to more closely mimic the procedures used by experts to rate habitats. The major changes to the model as a result of the field evaluation were (1) optimum suitability for the average diameter of overstory trees was changed from 25 to 38 cm; (2) snags were assigned greater importance than live trees for nesting; (3) the variable "percent canopy cover of pines" was added to reflect a strong negative correlation ($r=-0.91$, $P<0.001$) between this variable and habitat ratings by species authorities; (4) the mathematical function used to calculate the cover suitability index was changed from a geometric mean to a multiplicative function; and (5) the suitability relationship for tree canopy closure was changed from a preference for moderate canopy closure to a preference for dense forest canopy. Correlation of outputs from the modified model to habitat ratings by species authorities improved considerably ($r=0.82$, $P<0.001$) (O'Neil et al. 1988).

All of the changes to the model as a result of the field evaluation were based on input from species experts and reflect hairy woodpecker ecology in forests in the eastern United States. The variable "percent canopy cover of pines" is not recommended as an appropriate variable in western forests; use of the model in western vs. eastern forests is described below. The current model is the direct result of the field evaluation; it has not been field tested.

Model Description

Overview. The hairy woodpecker can satisfy all of its habitat requirements within any one of the forested cover types listed above. Reproductive and cover needs are evaluated in this model. Although sufficient food is an obvious life requisite of the hairy woodpecker, I assume in this model that food will never be more limiting than cover and reproductive requirements and that water is not a limiting factor.

The following sections identify important habitat variables, describe suitability levels of the variables, and describe the relationships between variables.

Reproduction component. The hairy woodpecker is able to adapt to a variety of habitats, but suitable reproductive habitats must (1) be dominated by trees of sufficient size and decay for nesting, (2) have adequate snag densities, or (3) have some combination of the two.

The number of snags ≥25.4 cm dbh necessary to support maximum densities of hairy woodpeckers has been estimated to range from 180/40 ha (Thomas et al. 1979) to 200/40 ha (Evans and Conner 1979), or 4.5 to 5 snags/ha; a snag density of 5/ha is assumed to represent optimal conditions for reproduction (Figure 1a). This estimate refers specifically to nesting and roosting requirements and may not adequately satisfy foraging needs (Conner, unpubl.). Potential population density is assumed to decrease proportionally with a decrease in snag density. Although I assume in this model that low snag densities will support low woodpecker densities, Bull (1978) assumed that snag densities <40% of those needed for maximum population density would not support a self-sustaining population.

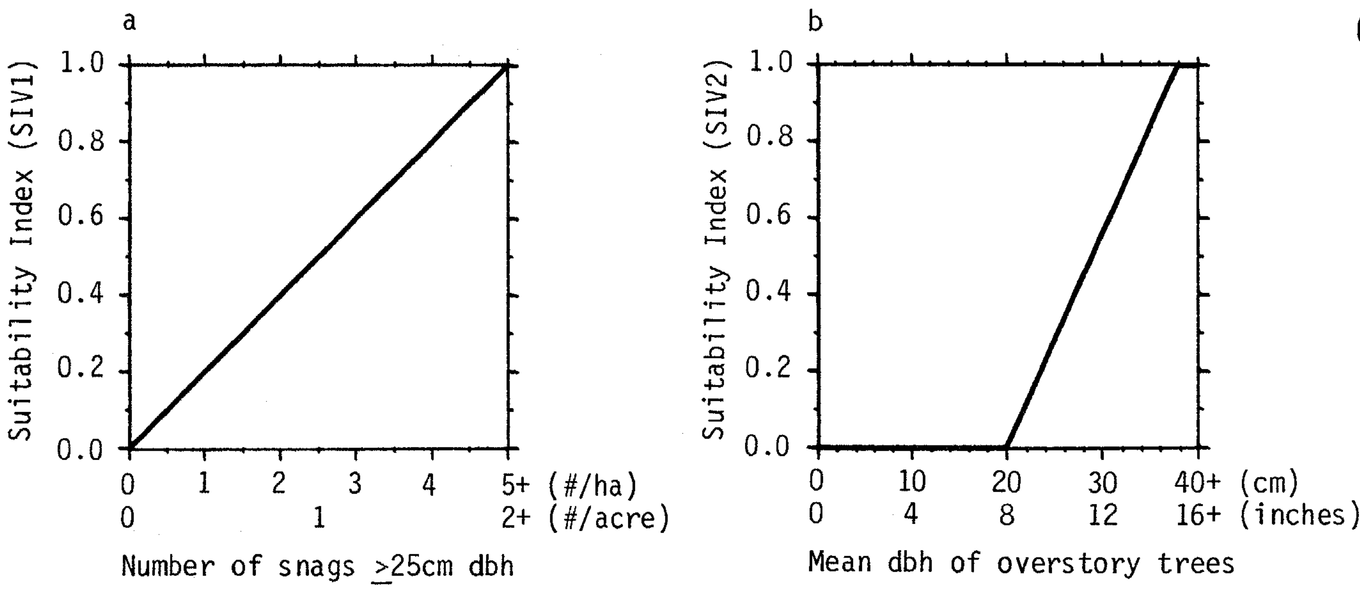


Figure 1. Relationships between variables used to evaluate reproductive habitat for the hairy woodpecker and suitability levels for the variables.

Hairy woodpeckers can excavate cavities in live trees provided that heartrot is present, and thus may inhabit a forested area even in the absence of snags. Runde and Capen (1987) believed that trees >30 cm dbh would be most useful to hairy woodpeckers, downy woodpeckers, and yellow-bellied sapsuckers (Syphrapicus varius). For this model, I assume that if the average dbh of overstory trees is ≥38 cm, then trees will be of optimum size for nesting. I assume that an adequate number of available (i.e., with heartrot) live trees will be present if the average dbh of overstory trees is ≥38 cm. There is little evidence correlating tree diameter and presence of heartrot, but the alternative is to physically examine trees for heartrot; this level of detail is presumed to be too great for the typical application of this model. Use of the average dbh of overstory trees does not consider the absolute number of available live trees. I assume that if an area meets the minimum requirements to be classified as a forest and is >4 ha, then the total number of trees available for potential nesting will be optimal. Assuming that adequate numbers of trees are present, the size and condition of the trees will determine whether the nesting potential will be low or high. The minimum reported dbh of a tree used for nesting by hairy woodpeckers is 20.1 cm (Conner et al. 1975). Thus, I assume that optimal conditions for this variable exist when the average dbh of overstory trees is ≥38 cm, and that conditions are unsuitable when the average dbh of overstory trees is ≤20 cm (Figure 1b). The values defining optimum and suitable levels of this variable are based on results of the field test mentioned earlier.

Overall nesting suitability is a function of the availability of snags or live trees. In the field test, experts consistently rated habitats without snags lower than habitats with snags (O'Neil et al. 1988), presumably because hairy woodpeckers cannot excavate in undecayed trees and prefer to forage on dead snags (Conner, unpubl.). Habitat suitability ratings in habitats without snags that were otherwise suitable were generally between 0.7 and 0.8 (on a 0-1 scale). I assume, therefore, that habitats without snags (i.e., all potential nest sites are in live trees) will have a maximum suitability rating of 0.75. An overall suitability index for nesting (SIN), based on the relationships described above, can be determined with Equation 1.

$$SIN = SIV1 + (0.75 \times SIV2) \qquad (1)$$

[Note: If the value resulting from Equation 1 exceeds 1.0, it should be set to 1.0.]

Cover component. Besides having sufficient potential nest sites, at least three other habitat factors affect the overall suitability of a habitat for hairy woodpeckers. These three factors are the seral stage of a forest stand, the degree of canopy cover of the forest, and the proportion of pines in the canopy. These variables are assumed to influence food availability, foraging, nesting suitability, and cover, but are aggregated into a cover component in this model. Because these factors affect overall habitat suitability, they will be used in this model as modifiers of the reproductive value.

A measure of the seral stage of a forest is the average diameter of the overstory trees. Hairy woodpeckers may inhabit young forests, but at lower densities than in older forests. Because they do inhabit forests in a variety of seral stages, however, this habitat variable should not be strictly limiting. I assume in this model that the optimal seral stage exists when the average dbh of overstory trees is >25 cm (Figure 2a). When the average dbh of overstory trees is <15 cm, suitability is assumed to be one-half of optimum, i.e., a suitability index of 0.5.

The literature suggests that hairy woodpeckers apparently prefer forests of moderate canopy cover. Habitat ratings by species experts in the field test, however, tended to be higher in forest stands with a dense canopy, except that closed canopy stands were generally rated lower than stands with <100% canopy cover (O'Neil et al. 1988). I assume that optimal conditions for this variable occur at 85% to 90% (Figure 2b) with complete canopy cover representing less than optimal habitat. I further assume that canopy cover <15% will provide unsuitable habitat conditions. Since the definition of a forest is a cover type with at least 25% tree canopy cover, any forest will have canopy conditions of some positive suitability level for hairy woodpeckers.

Hairy woodpeckers inhabit a variety of deciduous, coniferous, and mixed deciduous-coniferous habitats. Habitat ratings by experts were negatively correlated ($r=-0.91$, $P<0.001$) with the percent canopy closure of pines; sites completely dominated by pines received relatively low habitat ratings (O'Neil et al. 1988). I assume in this model that an increase in the canopy cover of pines in a stand will generally reflect a decrease in habitat suitability for the hairy woodpecker, although a small amount of pines (≤10% canopy cover) is assumed to contribute to the diversity of cover and prey (Figure 2c). Sites completely dominated by pines are assumed to have a suitability index for this variable of 0.2. The apparent influence of pines on hairy woodpecker habitat suitability described above probably does not apply in western coniferous forests (C.E. Bock, Environmental, Population and Organismic Biology, University of Colorado, Boulder; letter dated February 24, 1986). I recommend that the variable "percent canopy cover of pines" be deleted from the model for application in western coniferous forests. It is unclear whether a similar negative relationship exists between other species of conifers in eastern forests and perceived habitat suitability for the hairy woodpecker.

Results from the field test of the earlier model indicated that the product of the suitability indices (Equation 2) for the cover component variables most closely reflected habitat ratings by species experts (O'Neil et al. 1988).

$$SIC = SIV3 \times SIV4 \times SIV5 \qquad (2)$$

As long as an area is classified as a forested type, all of the variables in Equation 2 will be greater than zero, and the index value for the cover component will likewise be greater than zero.

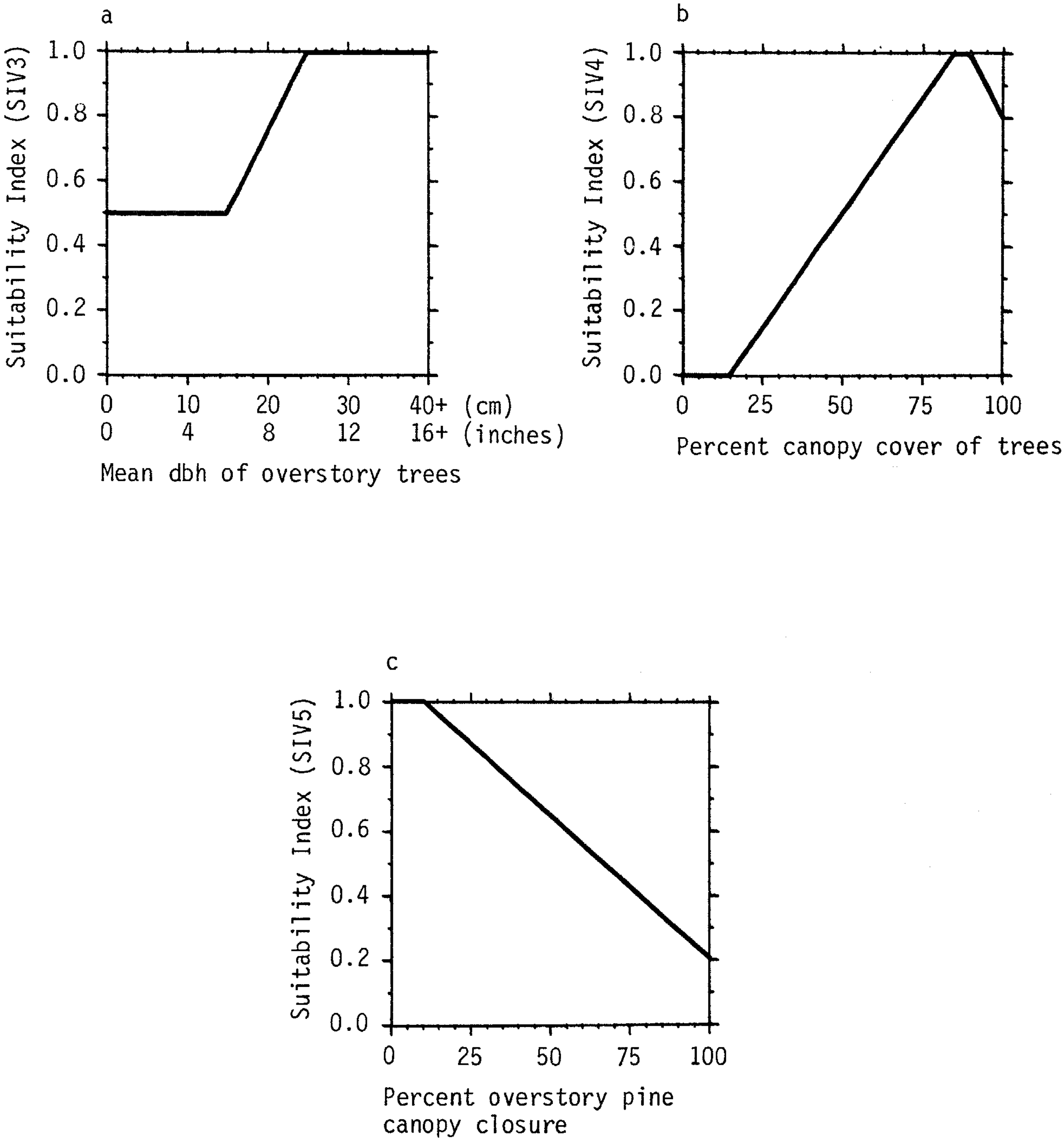


Figure 2. Relationships between variables used to evaluate cover for the hairy woodpecker and suitability levels for the variables.

HSI determination. The suitability index for the cover component is assumed to directly modify the suitability index for the reproduction component (Equation 3) to yield an overall HSI value for the hairy woodpecker in the habitat being evaluated. At optimal cover component conditions (i.e., SIC=1.0), the reproduction component will determine the habitat suitability index. If cover conditions are anything less than optimum, then the reproduction value will be reduced based on the quality of the cover conditions.

$$HSI = SIN \times SIC, \text{ or}$$

$$HSI = [SIV1 + (0.75 \times SIV2)] \times (SIV3 \times SIV4 \times SIV5) \qquad (3)$$

[Note: In instances where SIN >1.0, it should be set equal to 1.0 prior to using Equation 3.]

Application of the Model

Summary of model variables. Several habitat variables are used in this model to evaluate habitat suitability for the hairy woodpecker. The relationships between habitat variables, life requisites, cover types, and an HSI are summarized in Figure 3. The definitions and suggested measurement techniques (Hays et al. 1981) for the variables used in this model are listed in Figure 4.

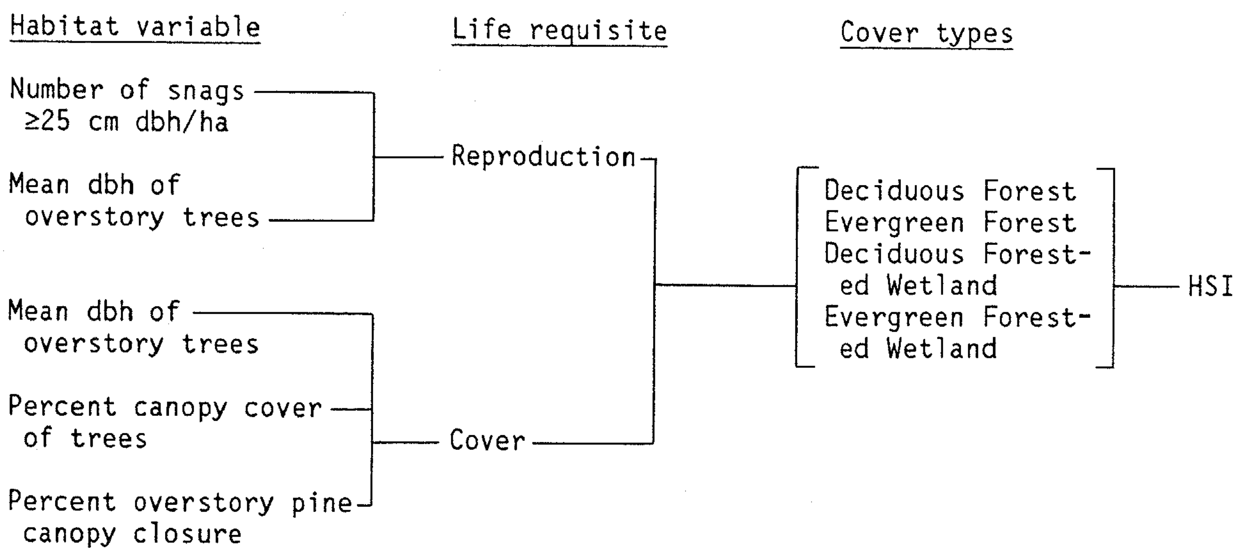


Figure 3. Relationships of habitat variables, life requisites, and cover types to the HSI for the hairy woodpecker.

Variable (definition)	Cover types	Suggested technique
Number of snags ≥25 cm dbh per ha [actual or estimated number of standing dead trees ≥25 cm dbh and ≥1.8 m tall. Trees in which ≥50% of the branches have fallen, or are present but no longer bear foliage, are to be considered snags].	DF,EF,DFW, EFW	Quadrat, remote sensing
Mean dbh of overstory trees [the mean diameter at breast height (1.4 m) above the ground of those trees that are ≥80% of the height of the tallest tree in the stand].	DF,EF,DFW, EFW	Diameter tape
Percent canopy cover of trees [the percent of the ground surface that is shaded by a vertical projection of all woody vegetation >6.0 m tall].	DF,EF,DFW, EFW	Line intercept, remote sensing
Percent overstory pine canopy closure [the percent of the ground surface that is shaded by a vertical projection of all pines (*Pinus* spp.) >6.0 m tall and ≥80% of the height of the tallest tree in the stand; recommended for use in eastern U.S. forests only (see text for explanation)].	DF,EF,DFW, EFW	Line intercept, remote sensing

Figure 4. Definitions of variables and suggested measuring techniques.

Model assumptions. A number of assumptions were made in the development of this HSI model.

1. The criteria identified for evaluation of hairy woodpecker habitat are generally assumed to be appropriate throughout the range of the species. Many of the variables and variable relationships identified in the model resulted from a field test of an earlier HSI model in eastern Tennessee. As a result, the model is probably best suited for application in the southeastern United States. No information is available to indicate the model's applicability to other parts of the United States, except there is adequate information that the presumed negative influence of pines does not apply to western U.S. forests (see number 7 below).

2. Nest sites can be provided by a combination of snags and live trees, but live trees in the absence of snags cannot provide optimal nesting habitat.

3. A measure of the average diameter at breast height of overstory trees is assumed to be an adequate estimator of the suitability of live trees for nesting. An adequate number of trees in suitable condition (i.e., with decayed heartwood) is assumed to be present as long as the cover type is classified as a forest (i.e., has ≥25% canopy cover) and tree diameter is suitable.

4. All tree species are assumed to be available for excavation by hairy woodpeckers. It is possible that some species may not typically have decayed heartwood and, therefore, will be unsuitable for excavation. It is also possible that some tree species will be unsuitable for excavation because of resins or the density of the wood. Little definitive evidence is available, however, to determine whether some tree species are absolutely unsuitable for excavation by hairy woodpeckers.

5. Hairy woodpeckers can inhabit a variety of forested habitats, but potential nesting in live trees will only be provided by older forest stands with large trees.

6. Hairy woodpeckers prefer forest stands with a dense canopy. This assumption may be valid in the southeastern United States but may be invalid in the western United States, where the forest canopy is generally less dense than in the east. The relationships described for percent canopy cover of trees and habitat suitability (Figure 2b) may need to be redefined for use in western forest habitat if the standard of comparison in such applications is intended to be the best regional habitat. Use of the model without modification will yield outputs based on a standard of comparison developed in the southeastern United States.

7. The presence of pines above a minimal level (10%) is considered to be a negative factor in habitat suitability for the hairy woodpecker in this model (Figure 2c). Pine and other coniferous forests in the western United States, however, are regularly used by hairy woodpeckers. I recommend that this variable be eliminated for application in western coniferous forests.

8. The hairy woodpecker breeds and winters throughout most of North America. I assume in this model that the year-round suitability of a habitat is a function of the habitat suitability during both the reproductive and nonreproductive seasons. Model users who wish to evaluate either of the seasons rather than both can simply use the appropriate portion of this model. Users should be aware that model outputs in such instances will refer only to a portion of the year-round needs of the hairy woodpecker.

SOURCES OF OTHER MODELS

Conner and Adkisson (1976) developed a model to distinguish between "possible nesing habitat" and "not nesting habitat" for the hairy woodpecker in oak-hickory forests of southwestern Virginia. Three variables were included in the model: basal area (m^2/ha), canopy height to crown cover (m), and stem density (number/ha). The model includes coefficients for the three variables, an aggregation function, and a linear decision scale. The model was applied to two groups, the first consisting of stands containing hairy woodpecker nests, and the second consisting of six random plots in each of five habitat types; results of the analysis were significant (P=0.02).

REFERENCES

American Ornithologists' Union. 1983. Check-list of North American birds. 6th ed. American Ornithologists' Union. Washington, DC. 877 pp.

Anderson, S.H., and H.H. Shugart, Jr. 1974. Habitat selection of breeding birds in an east Tennessee deciduous forest. Ecology 55(4):828-837.

Bailey, A.M., and R.J. Niedrach. 1965. Birds of Colorado. 2 Vols. Denver Mus. Nat. Hist., Denver, CO. 895 pp.

Balda, R.P., and N. Masters. 1980. Avian communities in the pinyon-juniper woodland. Pages 146-169 in R.M. DeGraaf and N.G. Tilghman, compilers. Management of western forests and grasslands for nongame birds. U.S. For. Serv. Gen. Tech. Rep. INT-86.

Beal, F.E.L. 1911. Food of the woodpeckers of the United States. U.S. Dept. Agric. Biol. Surv. Bull. 37. 64 pp.

Bull, E.L. 1978. Specialized habitat requirements of birds: snag management, old growth, and riparian habitat. Pages 74-82 in R.M. DeGraaf, tech. coord. Proceedings of the workshop on nongame bird habitat management in the coniferous forests of the western United States. U.S. For. Serv. Gen. Tech. Rep. PNW-64.

Calef, R.T. 1953. Ecological analysis of the flora and vertebrate fauna of Funks Forest National Area, McClean Co., Ill. M.S. Thesis. University of Illinois. 85 pp. [Cited by Graber et al. (1977).]

Conner, R.N. 1980. Foraging habitats of woodpeckers in southwestern Virginia. J. Field Ornith. 51(2):119-127.

Conner, R.N., and C.S. Adkisson. 1976. Discriminant function analysis: a possible aid in determining the impact of forest management on woodpecker nesting habitat. Forest Sci. 22(2):122-127.

Conner, R.N., and C.S. Adkisson. 1977. Principal component analysis of woodpecker nesting habitat. Wilson Bull. 89(1):122-129.

Conner, R.N., and H.S. Crawford. 1974. Woodpecker foraging in Appalachian clearcuts. J. For. 72:564-566.

Conner, R.N., R.G. Hooper, H.S. Crawford, and H.S. Mosby. 1975. Woodpecker nesting habitat in cut and uncut woodlands in Virginia. J. Wildl. Manage. 39(1):144-150.

Conner, R.N., O.K. Miller, Jr., and C.S. Adkisson. 1976. Woodpecker dependence on trees infected by fungal heart rots. Wilson Bull. 88(4):575-581.

Diem, K.L., and S.I. Zeveloff. 1980. Ponderosa pine bird communities. Pages 170-197 in R.M. DeGraaf and N.G. Tilghman, compilers. Management of western forests and grasslands for nongame birds. U.S. For. Serv. Gen. Tech. Rep. INT-86.

Evans, K.E., and R.N. Conner. 1979. Snag management. Pages 214-225 in R.M. DeGraaf and K.E. Evans, compilers. Management of northcentral and northeastern forests for nongame birds. U.S. For. Serv. Gen. Tech. Rep. NC-51.

Fitch, H.S. 1958. Home ranges, territories, and seasonal movements of vertebrates of the Natural History Reservation. Univ. Kansas Publ. Mus. Nat. Hist. 11(3):63-326.

Galli, A.E., C.F. Leck, and T.T. Forman. 1976. Avian distribution patterns in forest islands of different sizes in central New Jersey. Auk 93(2):356-364.

Gamboa, G.J., and K.M. Brown. 1976. Comparative foraging behavior of six sympatric woodpecker species. Proc. Iowa Acad. Sci. 82:179-181.

Graber, J.W., R.R. Graber, and E.L. Kirk. 1977. Illinois birds: Picidae. Illinois Nat. Hist. Surv. Biol. Notes 102. 73 pp.

Haapanen, A. 1965. Bird fauna of the Finnish forests in relation to forest succession. I. Ann. Zool. Fenn. 2:154-196. [Cited by Smith (1980).]

Hardin, K.I., and K.E. Evans. 1977. Cavity nesting bird habitat in the oak-hickory forest ... a review. U.S. For. Serv. Gen. Tech. Rep. NC-30. 23 pp.

Hays, R.L., C. Summers, and W. Seitz. 1981. Estimating wildlife habitat variables. U.S. Fish Wildl. Serv. FWS/OBS-81/47. 111 pp.

Jackman, S.M. 1975. Woodpeckers of the Pacific Northwest: their characteristics and their role in the forests. M.S. Thesis. Oregon State University, Corvallis. 147 pp.

Kilham, L. 1968. Reproductive behavior of hairy woodpeckers. II. Nesting and habitat. Wilson Bull. 80(3):286-305.

Kisiel, D.S. 1972. Foraging behavior of *Dendrocopus villosus* and *D. pubescens* in eastern New York state. Condor 74(4):393-398.

Koplin, J.R. 1967. Predatory and energetic relations of woodpeckers to the Engelmann spruce beetle. Ph.D. Dissertation. Colorado State University, Ft. Collins. 187 pp.

Kroll, J.C., and R.R. Fleet. 1979. Impact of woodpecker predation on overwintering within-tree populations of the Southern pine beetle (*Dendroctonus frontalis*). Pages 269-281 *in* J.G. Dickson, R.N. Conner, R.R. Fleet, J.C. Kroll, and J.A. Jackson, eds. The role of insectivorous birds in forest ecosystems. Academic Press, New York.

Larrison, E.J., and K.G. Sonnenberg. 1968. Washington birds: their location and identification. Seattle Audubon Society, Seattle. 258 pp.

Lawrence, L. DeK. 1966. A comparative life-history study of four species of woodpeckers. Ornithol. Monogr. No. 5, American Ornithologists' Union. 156 pp.

Mannan, R.W. 1977. Use of snags by birds, Douglas-fir region, western Oregon. M.S. Thesis. Oregon State University, Corvallis. 114 pp.

Mannan, R.W., E.C. Meslow, and H.M. Wight. 1980. Use of snags by birds in Douglas-fir forests, western Oregon. J. Wildl. Manage. 44(4):787-797.

Massey, C.L., and N.D. Wygant. 1973. Woodpeckers: most important predators of the spruce beetle. Colorado Field Ornithol. 16:4-8.

Meslow, E.C., and H.M. Wight. 1975. Avifauna and succession in Douglas-fir forests of the Pacific Northwest. Pages 266-271 in D.R. Smith, tech. coord. Management of forest and range habitats for nongame birds. U.S. For. Serv. Gen. Tech. Rep. WO-1.

Noon, B.R., V.P. Bingham, and J.P. Noon. 1979. The effects of changes in habitat on northern hardwood forest bird communities. Pages 33-48 in R.M. DeGraaf and K.E. Evans, compilers. Management of northcentral and northeastern forests for nongame birds. U.S. For. Serv. Gen. Tech. Rep. NC-51.

O'Neil, L.J., T.H. Roberts, J.S. Wakeley, and J.W. Teaford. 1988. A procedure to modify Habitat Suitability Index models. Wildl. Soc. Bull. 16(4):In press.

Raphael, M.G., and M. White. 1984. Use of snags by cavity-nesting birds in the Sierra Nevada. Wildl. Monogr. 86. 66 pp.

Robbins, C.S. 1979. Effects of forest fragmentation on bird populations. Pages 199-212 in R.M. DeGraaf and K.E. Evans, compilers. Management of northcentral and northeastern forests for nongame birds. U.S. For. Serv. Gen. Tech. Rep. NC-51.

Runde, D.E., and D.E. Capen. 1987. Characteristics of northern hardwood trees used by cavity-nesting birds. J. Wildl. Manage. 51(1):217-223.

Scott, V.E., J.A. Whelan, and P.L. Svoboda. 1980. Cavity-nesting birds and forest management. Pages 311-324 in R.M. DeGraaf and N.G. Tilghman, compilers. Management of western forests and grasslands for nongame birds. U.S. For. Serv. Gen. Tech. Rep. INT-86.

Smith, K.G. 1980. Nongame birds of the Rocky Mountain spruce-fir forests and their management. Pages 258-279 in R.M. DeGraaf and N.G. Tilghman, compilers. Management of western forests and grasslands for nongame birds. U.S. For. Serv. Gen. Tech. Rep. INT-86.

Stallcup, P.L. 1966. Spatio-temporal relationships of nuthatches and woodpeckers in northern Colorado. Ph.D. Dissertation. Colorado State University, Ft. Collins. 111 pp.

Stauffer, D.F., and L.B. Best. 1980. Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. J. Wildl. Manage. 44(1):1-15.

Thomas, J.W., R.G. Anderson, C. Maser, and E.L. Bull. 1979. Snags. Pages 60-77 in J.W. Thomas, tech. ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. U.S. For. Serv. Agric. Handb. 553.

U.S. Fish and Wildlife Service. 1981. Standards for the development of Habitat Suitability Index models. 103 ESM. U.S. Fish Wildl. Serv., Div. Ecol. Serv. n.p.

Verner, J. 1980. Bird communities of mixed-conifer forests of the Sierra Nevada. Pages 198-223 in R.M. DeGraaf and N.G. Tilghman, compilers. Management of western forests and grasslands for nongame birds. U.S. For. Serv. Gen. Tech. Rep. INT-86.

Zarnowitz, J.E., and D.A. Manuwal. 1985. The effects of forest management on cavity-nesting birds in northwestern Washington. J. Wildl. Manage. 49(1):255-263.

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. Biological Report 82(10.146)	2.	3. Recipient's Accession No.
4. Title and Subtitle Habitat Suitability Index Models: Hairy Woodpecker			5. Report Date September 1987
			6.
7. Author(s) P. J. Sousa			8. Performing Organization Rept. No.
9. Performing Organization Name and Address National Ecology Research Center U.S. Fish and Wildlife Service Drake Creekside One Bldg. 2627 Redwing Rd. Fort Collins, CO 80526-2899			10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address National Ecology Research Center Research and Development Fish and Wildlife Service Department of the Interior Washington, DC 20240			13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for the hairy woodpecker (Picoides villosus). The model consolidates habitat use information into a framework appropriate for field application, and is scaled to produce an index between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). HSI models are designed to be used with Habitat Evaluation Procedures previously developed by the U.S. Fish and Wildlife Service.

17. Document Analysis a. Descriptors

Birds
Wildlife
Habitability
Mathematical models

b. Identifiers/Open-Ended Terms

Hairy woodpecker
Picoides villosus
Habitat suitability

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release unlimited	Unclassified	19
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

☆ U.S. GOVERNMENT PRINTING OFFICE: 1988—574-162/85,052 REGION NO. 8

Great Trinity Forest Management Plan

Wildlife Management

Raccoon

(Procyon lotor)

Raccoon
(*Procyon lotor*)

The raccoon is a medium sized, nocturnal mammal that inhabits most of North and South America. This species is frequently considered a pest but it is also an important fur and game species. They will thrive in a variety of habitats, from swamps to urban areas, but they are most abundant near water. Predators include foxes, bobcats (*Lynx rufus*), coyotes (*Canis latrans*) and owls (U.S. Fish and Wildlife Service 1980, Whitaker and Hamilton 1998, Zeveloff 2002).

Food

Raccoons are omnivores and highly opportunistic. They will eat mast (such as acorns (*Quercus* spp.), persimmons (*Diospyros* spp.), grapes (*Vitis* spp), pokeweed (*Phytolacca* spp.), blackberries (*Rubus* spp) and mulberries (*Morus* spp)), insects, invertebrates, crayfish and small rodents. One study by Hendricks (1975) on the diet of raccoons in East Texas showed that plant matter actually made up more than half of the diet throughout the year. Raccoons are also considered an "important nest predator of ground nesting birds and other species" (Henner et al 2004) and may need to be controlled by manipulating den sites or using other management activities (Hendricks 1975, U.S. Fish and Wildlife Service 1980, Whitaker and Hamilton 1998).

Water

Raccoons require free water daily and can use these areas for foraging. Therefore, U.S. Fish and Wildlife Service suggests that there should be 3 or more permanent water holes per 2.6 km^2 (1 mi^2) in the southeastern United States (U.S. Fish and Wildlife Service 1980).

Habitat

Optimum habitat is a combination of hardwood forests and wetlands with an interspersion of grassy and early successional areas. This combination of habitats supplies insects, aquatic animals, small mammals, reptiles, hard and soft mast. However, raccoons are an adaptable species that does very well in urban areas. In fact, one study in Illinois found that raccoon density was actually higher in urban areas than in rural areas due to smaller home ranges and a stable supply of food. Ranges of raccoons normally range from 40 to 100 ha (100-250 acres) and are generally about 80 ha (200 ac) in the Southeast. Densities can range between low (fewer than 5/km^2) to the highest recorded density of 250/km^2 (1/ ac) (U.S. Fish and Wildlife Service 1980, Whitaker and Hamilton 1998, Zeveloff 2002, Randa and Yunger 2006).

Cover

In summer, raccoons need temporary daytime dens but these dens can be in almost any type of shelter from clumps of Spanish moss (*Tillandsia usneoides*) to blackberry thickets. Raccoons also use tree dens for bearing young, winter sleep (not hibernation) and temporary shelter, but these can be limiting in some areas. However, if these sites are scarce, raccoons will use burrows of other mammals, brush piles, buildings, crevices, etc. The importance of tree cavities is shown in a study conducted in a forested habitat which found that females used cavity trees 94% of the time during the breeding season and selected sites near mast and water. During cub-rearing, cavity trees were also used but not as often because of plentiful food and mild weather. One study in a Mississippi prairie found that females use cavity dens frequently for young rearing while males tended to use brush piles and ground dens. The study concluded that "availability of woody habitat, free water and quality foraging areas with abundant edge are important to raccoon denning behavior" (Henner et al. 2004). A study in Michigan found that tree dens on average where 29 by 36 cm (11.5 by 14 in) and were between 3 - 12 m (10 - 42.6 ft) above the ground, but some dens may be as high as 21 m (70 ft) above the ground. Tree dens are usually near water and several studies have shown that the average distance to water is 67 - 140 m (220 - 460 ft) but it can be as far as 0.4 km (0.25 mi) (U.S. Fish and Wildlife Service 1980, Whitaker and Hamilton 1998, Zeveloff 2002, Henner et al. 2004, Wilson and Nielson, 2006).

Management

The limiting factors usually are the availability of suitable habitat, late winter food and den trees. Therefore, den and mast producing trees should be protected and promoted. To provide dens, hardwood forests should be on at least 100-year rotations, which will provide mature or overmature trees with a dbh greater than 50 cm (20 in). Any den trees present should be protected so that there is at least 1 - 2 dens per 6 - 8 ha (1 - 2 dens per 15 - 20 ac) and 2 - 3 times that many potential den sites. If dens are limiting, then nest boxes may also be used (U.S. Fish and Wildlife Service 1980, Zeveloff 2002).

Literature Cited

U.S. Fish and Wildlife Service. 1980. Habitat Suitability Index Models: Raccoon. U.S. Department of the Interior, Fish and Wildlife Service. Review Copy. 108 pp.

Hendricks, R.B. 1975. Food Habits of the Raccoon, Procyon lotor, in East Texas. Thesis, Stephen F. Austin State University, Nacogdoches, Texas, USA.

Henner, C.M., M.J. Chamberlain, B.D. Leopold, and L.W. Burger, Jr. 2004. A Multi-Resolution Assessment of Raccoon Den Selection. Journal of Wildlife Management 68(1):179–187

Randa, L.A. and J.A. Yunger. 2006. Carnivore Occurrence Along an Urban–Rural Gradient: A Landscape-Level Analysis. Journal of Mammalogy, 87(6):1154–1164

Wilson, S.E. and C.K. Nielsen. 2006. Habitat Characteristics of Raccoon Daytime Resting Sites in Southern Illinois. Am. Midl. Nat. 157:175–186

Whitaker, Jr. J.O. and W.J. Hamilton, Jr. 1998. Mammals of the Eastern United States. Cornell University Press, Ithaca, New York, USA.

Zeveloff, S.I. 2002. Raccoons: A Natural History. Smithsonian Institution, Washington, D.C., USA.

<u>Great Trinity Forest Management Plan</u>

Wildlife Management

Habitat Suitability Index Model: Raccoon

RACCOON

Species Narrative

General. The raccoon (Procyon lotor) is an important fur and game species in the southeastern United States (Halls and Stransky 1971). Coastal swamps, marshes, and bottomland hardwoods consistently support the highest populations (U.S. Forest Service 1971). Raccoons, when they inhabitat upland pine-hardwood or hardwood forests, are usually found near rivers, small streams, or swamps (Halls and Stransky 1971).

Food Requirements. The diet of the raccoon includes an almost unlimited variety of plant and animal food (Stuewer 1943). Food habits depend on availability, individual preference, and learning, although raccoons are usually more selective in times of abundant food supplies (Johnson 1970). Fruits were eaten whenever they were available in Alabama. Invertebrates were eaten throughout the year but were most important in late winter and spring. Acorns were preferred foods in the fall; they are often considered essential for raccoon survival during the winter. The availability of late winter foods may be limiting for raccoons in some areas of the Southeast.

Acorns and crayfish were the main foods of raccoons in eastern Texas throughout the year (Baker et al. 1945). Foraging areas included both bottomland and adjacent upland woods. Raccoons utilize upland areas more in the summer and fall when they are feeding on fruits (such as persimmons (Diospyros spp.), acorns, mulberry (Morus spp.), French mulberry, and grape (Vitis spp.)), and insects. Foraging is more concentrated in bottomlands during the winter and spring when acorns, crayfish, and aquatic prey are eaten. Persimmons, pecans, grapes, pokeweed (Phytolacca spp.), corn, crayfish, insects, birds, snails, fish, and small mammals were eaten by raccoons in Georgia (Golley 1962).

Water Requirements. Raccoons require free water daily (Stuewer 1943). Wetland areas also provide excellent foraging habitat. Three or more permanent water holes per 2.6 km^2 (1 mi^2) are recommended in areas managed for raccoons in the southeastern United States (U.S. Forest Service 1971).

Cover Requirements. Raccoons are nocturnal and generally solitary (Schwartz and Schwartz 1959). Communal dens may be used during severe weather, in periods of high population density, or in the vicinity of abundant food supplies.

Raccoons are excellent swimmers and climbers (Lowery 1974). They use both ground and tree dens for shelter and escape cover although tree dens are preferred for raising young (U.S. Forest Service 1971). Schnell (1969-1970) reported two distinct types of rest sites being utilized by raccoons in Minnesota: 1) sites in upland habitats which were reached by climbing trees, and 2) sites in lowland habitats which were on or close to the ground substrate. Approximately 74% of 173 recorded resting sites were located in swamps, 17% were situated in hollow trees and 9% were located in the abandoned nests of squirrels or birds. All leaf/twig nests of birds or squirrels utilized for shelter by raccoons were located in stands of deciduous vegetation and were typically situated near marsh or open water. With the exception that tree dens used by raccoons did not have ground surface entrances, tree den characteristics were highly variable. Raccoons never rested on the ground in upland field or woods habitat types, however, ground rest sites were common in lowland habitat types.

Overmature hardwoods, including live oaks (Quercus virginiana), yellow poplar (Liriodendron tulipifera), magnolia (Magnolia spp.), and cypress (Taxodium distichum), are among the preferred den trees in the Southeast (U.S. Forest Service 1971). Den cavities are usually within, or just below, the tree canopy and may be 21 m (70 ft) or more above the ground. Den trees within 0.4 km (0.25 mi) of a permanent water supply are preferred. Suitable cavities have 10 to 25 cm (4 to 10 in) openings facing away from prevailing winds, are at least 4.5 m (15 ft) above ground, and sheltered enough to stay dry. A raccoon may have several dens within its range and does not necessarily use the same den continuously (Schwartz and Schwartz 1959). Den trees are most frequently found in bottomland forests.

Tree cavities may not be essential for providing den sites, or escape and thermal retreats (Dorney 1954; Golley 1962; Davis 1974). The lack of suitable den trees may, however, be limiting in the Southeast (Halls and Stransky 1971).

Raccoons remain active throughout the winter in the South (Halls and Stransky 1971), although they may retreat to tree dens or ground burrows for several days at a time during severe weather (Berner and Gysel 1967). Large trees that retain their foliage through the winter also serve as refuge sites during cold weather (Johnson 1970).

Reproductive Requirements. The raccoons' reproductive requirements are synonymous with the cover requirements described above.

Interspersion Requirements. Raccoons are primarily a forest and marsh species, although they will use a variety of habitats (U.S. Forest Service 1971). Habitat preference in descending order is generally bottomland hardwoods, marshes, cultivated areas, fields of tall weeds and broomsedge (*Andropogon* spp.), upland hardwoods, pine-hardwoods, and pine (*Pinus* spp.). A diversity of habitat is needed to provide a variety of feeding opportunities during all seasons (Johnson 1970). The combination of hardwood forests with wetlands supplies mast, insects, and aquatic animal life (U.S. Forest Service 1971). The interspersion of open areas increases the availability of fruits, berries, insects, small mammals, and reptiles. Grassy openings for insect production and areas in early successional stages (containing plum (*Prunus* spp.), blackberries (*Rubus* spp.), black cherry, persimmon, greenbriers (*Smilax* spp.), privet (*Ligustrum* spp.), and other fruit-producing species) help to provide optimal habitat for raccoons (Johnson 1970).

Hardwood trees, either in a dense stand or as a narrow strip bordering a wetland area, are preferred raccoon habitat in Missouri (Schwartz and Schwartz 1959). The most suitable raccoon habitat in eastern Texas occurs along streams where wide floodplains and adjacent sloping uplands support mature stands of oaks and other hardwoods (Baker et al. 1945). The interspersion of marsh or swamp with stands of bottomland mast-producing trees provides optimal habitat in coastal areas (Urban 1970). Raccoons are common in fresh and salt water marshes (Golley 1962) and these wetlands are often key habitat for raccoons because of the food and protection they provide (U.S. Forest Service 1971).

Raccoon home ranges often overlap (Golley 1962). Movements are primarily along stream courses and are probably related to food availability and preferences (Johnson 1970). Raccoons have small, shifting centers of activity within a much larger area of general familiarity. There is much individual variation in movement and raccoons may forage far outside their usual home area if an especially attractive food supply, such as corn, a plum or privet thicket, or an abundant supply of persimmons, is available. Home ranges in the Southeast are about 80 ha (200 ac) and vary from 0.8 to 2.4 km (0.5 to 1.5 mi) in diameter (U.S. Forest Service 1971).

Habitat deficiencies are major limiting factors in many areas, even though raccoons are a very adaptable species (Johnson 1970). The most important limiting factors are usually the availability of late winter food and den trees.

Special Considerations. Raccoons are very sensitive to the destruction of mature hardwood stands. The preservation of den trees, wetland areas, and fruit and mast-producing plants is critical. Stands with 20% mast-producing trees are desirable in the Southeast, and 100-year rotations in upland and bottomland hardwood forests are necessary for the adequate production of mast and den cavities (U.S. Forest Service 1971). Management plans for raccoons in Michigan include leaving at least 1 to 2 dens/6 to 8 ha (1 to 2 dens/15 to 20 ac) and at least 2 to 3 times that many potential den sites (Stuewer 1943). Clear-cutting, overharvesting, and stream siltation are detrimental to raccoon populations (Stains 1956).

Raccoons have readily adapted themselves to land occupied by man (Stains 1956) and agricultural crops may have local importance when natural foods are not readily available (Johnson 1970).

REFERENCES CITED

Baker, R. H., C. C. Newman, and F. Wilke. 1945. Food habits of the raccoon in eastern Texas. J. Wildl. Manage. 9(1):45-48.

Berner, A., and L. W. Gysel. 1967. Raccoon use of large tree cavities and ground burrows. J. Wildl. Manage. 31(4):706-714.

Davis, W. E. 1974. The mammals of Texas. Texas Parks and Wildl. Dept., Austin. Bull. 41. 294 pp.

Dorney, R. S. 1954. Ecology of marsh raccoons. J. Wildl. Manage. 18(2):217-225.

Golley, F. B. 1962. Mammals of Georgia. Univ. Georgia Press, Athens. 218 pp.

Halls, L. K., and J. J. Stransky. 1971. Atlas of southern forest game. U.S.D.A. For. Serv., Southern For. Exp. Stn. 24 pp.

Johnson, A. A. 1970. Biology of the raccoon (Procyon lotor varius) Nelson and Goldman in Alabama. Agric. Exp. Stn., Auburn Univ., Auburn. 148 pp.

Lowery, G. H., Jr. 1974. The mammals of Louisiana and its adjacent waters. Louisiana State Univ. 565 pp.

Schnell, J. H. 1969-1970. Rest site selection by radio-tagged raccoons. J. Minn. Acad. Sci. 36(2 & 3):83-88.

Schwartz, C. W., and E. R. Schwartz. 1959. The wild mammals of Missouri. Univ. Missouri Press, Kansas City. 341 pp.

Stains, H. J. 1956. The raccoon in Kansas; natural history, management, and economic importance. Univ. Kansas Mus. Nat. Hist. Misc. Publ. 10:1-76.

Stuewer, F. W. 1943. Raccoons: their habits and management in Michigan. Ecol. Monogr. 13:203-258.

Urban, D. 1970. Raccoon populations, movement patterns, and predation on a managed waterfowl marsh. J. Wildl. Manage. 34(2):372-382.

U.S. Forest Service. 1971. Wildlife habitat management handbook. U.S.D.A. For. Serv., Southern Region. FSH 2609.23R. Unpaged.

Habitat Suitability Index (HSI) Model for the Raccoon

General Information

Species Information

Species:	Raccoon (Procyon lotor)
Habitat Use Pattern:	Single cover type user
Status:	Resident
Cover Types:	Evergreen Forest (EF), Deciduous Forest (DF), Deciduous Forested Wetland (DFW), Shrubland (S), Deciduous Shrub Wetland (DSW), Herbland/Savanna (H/S), and Herbaceous Wetland (HW)
Ecoregion:	2320 South
Model Type:	Uncalibrated Index Model

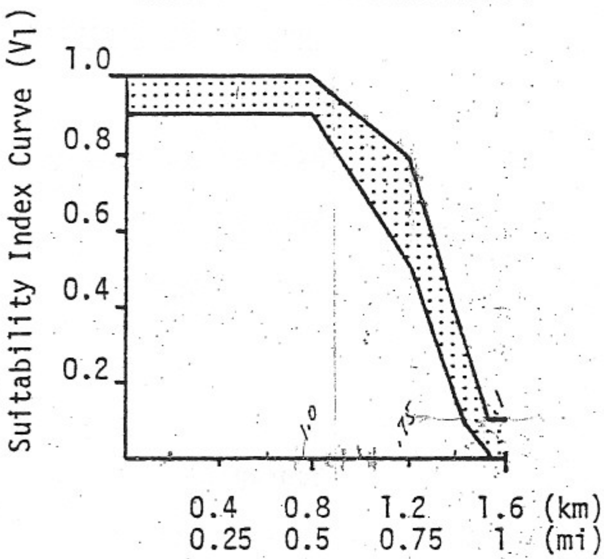
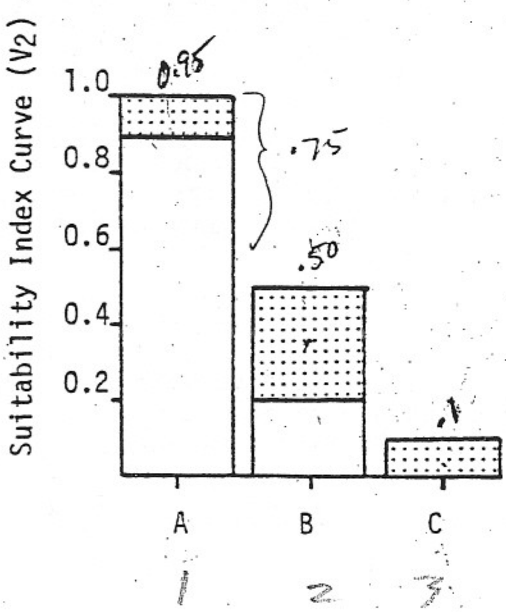
Threshold Range Size. Home ranges for the raccoon vary between 0.8 to 2.4 km (0.5 to 1.5 mi) in diameter, however, there is much variation in movement and raccoons may forage far outside their usual home area

Habitat Composition. Mature stands of hardwoods adjacent to or interspersed with permanent water (streams, rivers, ponds, lakes) will provide optimal habitat for the raccoon. Other cover types will provide suitable habitat if water and adequate refuge sites are available.

Evaluation Criteria (by cover types)

Food Value - The raccoon feeds upon an almost unlimited variety of plant and animal foods. It is assumed that the availability of food will not be limiting for the raccoon in this Ecoregion.

Water Value - Raccoons require free water for drinking and foraging.

Cover Type	Variable		Suitability Index Curve
EF, DF, DFW, S, DSW, H/S, HW	[V_1]	Distance to water.	
EF, DF, DFW, S, DSW, H/S, HW	[V_2]	Water regime. A) Permanent water B) Semi-permanent water C) No water, or ephemeral flooding.	

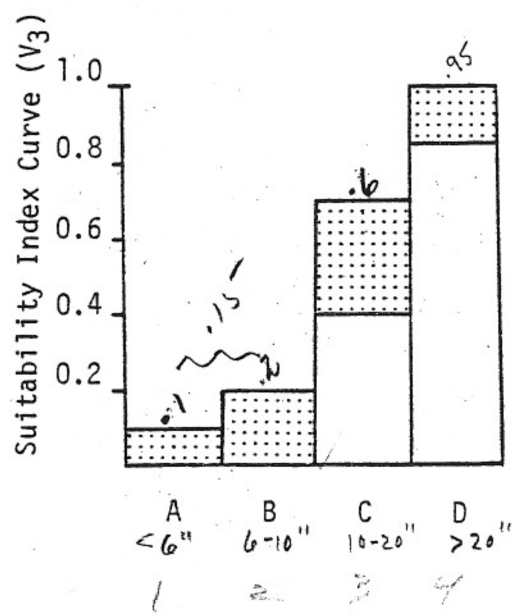
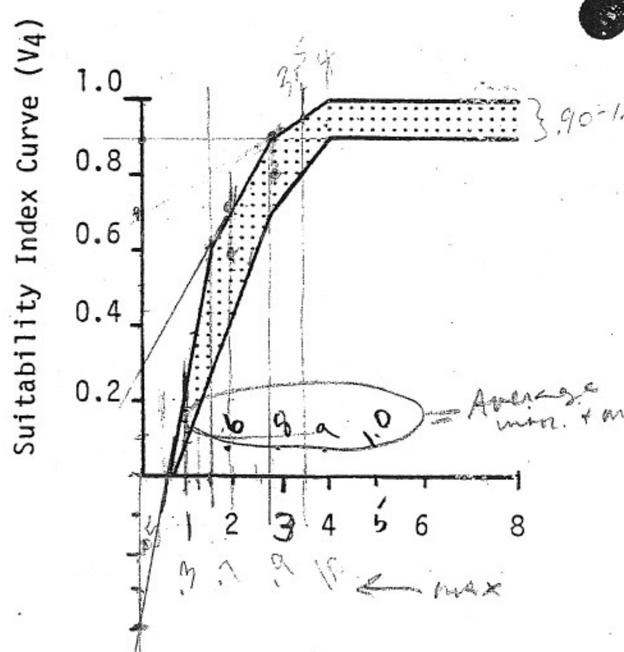
=IF(T89>5280,0.1,IF(T89>3960,(
IF(T89>2640,
IF(T89>0,1,0)

Water Value for all cover types is a function of V_1 and V_2. A low suitability for one variable will be compensated for by a high score in the remaining variable. The suggested function is:

$$(V_1 \times V_2)^{1/2}$$

Cover and Reproductive Value. Mature and overmature hardwood stands will generally provide wolf trees, snags and cavities necessary to meet the cover and reproductive requirements of the raccoon.

Although raccoons prefer to utilize tree dens as refuge and reproductive sites, ground burrows, rock crevices, caves, brush piles, and windthrow may be used for the same purpose.

Cover Type	Variable		Suitability Index Curve
EF,DF, DFW,H/S	[V_3]	Overstory forest size class. A) Saplings (< 15 cm (6 in) dbh). B) Pole timer (≥ 15 cm (6 in) to 25 cm (10 in) dbh). C) Sawtimber (≥ 25 cm (10 in) to 50 cm (20 in) dbh). D) Mature trees (≥ 50 cm (20 in) dbh).	
EF,DF, DFW,S, DSW,H/S, HW	[V_4]	Number of refuge sites per 0.4 ha (1 ac). (Refuge sites include ground burrows, rock crevices, caves, brushpiles, and windthrow.)	

Cover and Reproductive Value in evergreen forest, deciduous forest, deciduous forested wetland, and herbland/savanna is a function of V_3 and V_4. A low value for one variable will be compensated for by a high value in the remaining variable. The suggested function is:

$$\frac{V_3 + V_4}{2}$$

S, DSW, HW

Cover and Reproductive Value in shrubland, deciduous shrub wetland, and herbaceous wetland is a function of V_4. *

Determination of the Habitat Suitability Index. The HSI equals the lowest life requisite value.

Model Assumptions and Limitations. It is assumed in this model that food availability will not be limiting for the raccoon.

Great Trinity Forest Management Plan

Wildlife Management

Red-tailed Hawk

(Buteo jamaicensis)

Red-tailed Hawk
(*Buteo jamaicensis*)

The red-tailed hawk "has the widest ecological tolerance and geographic distribution of any buteo in North America" (U.S. Fish and Wildlife Service 1980), which is why it is the most widespread and commonly observed birds of prey in North America (U.S. Fish and Wildlife Service 1980, Preston and Beane 1993).

Food

This is an opportunistic predator which forages in open areas mainly by using perches (60-80%). This hawk mainly feeds on small to medium sized mammals such as voles, mice, rats, cottontails, and tree squirrels; however, it also eats medium sized birds, large insects, reptiles and carrion (U.S. Fish and Wildlife Service 1980, Preston and Beane 1993).

Water

Generally, waster is not a limiting factor since these hawks obtain it mostly from metabolic process of digesting food (U.S. Fish and Wildlife Service 1980).

Habitat

Red-tailed hawks usually inhabit forested sites interspersed with or adjacent to open areas. It is a very adaptive bird which will tolerate "a broad array of forest structures" (La Sorte et al 2004). Since this hawk is a sit and wait predator, perches in these open areas are vital. In fact, prey availability in the form of adequate perch sites and open areas has been found to be correlated with reproductive success and improved habitat quality (Stout et al 2006). In a Michigan study, all perch trees used were 9 - 20.7 m (30 - 70 ft) tall. Ranges of these birds can vary but reported ranges ranged from 119 ha (298 ac) to 256 ha (640 ac) and it is suggested that at least 518 ha (1,280 ac) is needed to maintain a viable breeding population (U.S. Fish and Wildlife Service 1980, Preston and Beane 1993).

Reproduction

Red-tailed hawks usually nest in mature trees in open woodlots or along woodlot edges. Though this species is generally very tolerant of humans, it usually nests well away from human dwellings. One study in Michigan found no nests within 370m (411yds) of human dwellings; in fact, a pair will often abandon a nest under construction if they detect human presence. However, Stout et al. (2006) found that urban areas can provide high quality habitat for red-tailed hawks and that this species will use man-made structures such as transmission towers and billboards for nesting structures. In fact, Stout et al. (2006) found that "nesting success and productivity for nests on human-made structures were higher than for nests in trees" and suggested that nesting in these structures provided nesting sites that were more stable than most natural structures and may be difficult for mammalian predators to climb. Nests are typically 71 - 76 cm (28 - 29.9 in) in outside diameter and are frequently reused year after year. Nest trees are often taller than surrounding trees, with unobstructed access from above and a view of the surrounding area. In several studies conducted in northern U.S. the average diameter at breast height (DBH) of nest trees ranged from 52.3cm (20.9in) to 64 cm (25in) and the average nest tree height in one study was 23.6 ± 3.3 m (77.8 ± 10.9 ft) (U.S. Fish and Wildlife Service 1980, Preston and Beane 1993).

Management

Preston and Beane (1993) list this species greatest threats as shooting pressure, automobile collision and human interference with nesting activities. However, a population may also be limited by nest sites and food supply. The optimal habitat composition of an area should be 70 - 90% of cover types that provide food while 10 - 30% should be comprised of cover types that provide cover and reproduction.
In cover types that provide food:

- In pastureland, grassland and forb land the optimum conditions are a more than 75% herbaceous canopy cover and more than 50% herbaceous canopy that is 15 to 60 cm (6 - 24 in) tall.
- In tree savannas, shrubland or shrub savannas the optimum conditions are same as above but the shrub crown closure should be 40 - 60%.
- In cropland the optimum conditions are grain or vegetable crops with a mature height of less than 0.9m (3 ft) and when crop residues are abundant and remain on the surface.
- In forested land the canopy closure of overstory trees should be 30 - 50% and less than or equal to 800 woody stems (greater than 1m tall) per 0.4 ha (1ac).

In cover types that provide cover and reproduction the optimal condition is less than or equal to 15 trees that are more than 50 cm (20 in) dbh per 0.4 ha (1.0 ac). The distance between cover types should not exceed 3.6 km (2.25mi) with an optimum distance less than1.2 km (0.75 mi). In urban areas, land managers should protect high quality habitat and can created green areas next to roads and highways which the birds can hunt for prey in (U.S. Fish and Wildlife Service 1980, Preston and Beane 1993, Stout et al 2006).

Literature Cited

U.S. Fish and Wildlife Service. 1980. Habitat Suitability Index Models: Red-Tailed Hawk. U.S. Department of the Interior, Fish and Wildlife Service. Review Copy. 173 pp.

La Sorte, F.A., R.W. Mannan, R.T. Reynolds, and T.G. Grubb. 2004. Habitat associations of sympatric red-tailed hawks and northern goshawks on the Kaibab Plateau. Journal of Wildlife Management 68(2):307–317

Preston, C. R., and R. D. Beane. 1993. Red-tailed Hawk (*Buteo jamaicensis*). *In* The Birds of North America, No. 52 (A. Poole, and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

Stout, W.E., S.A. Temple, and J.M. Papp. 2006. Landscape Correlates of Reproductive Success for an Urban–Suburban Red-Tailed Hawk Population

Great Trinity Forest Management Plan

Wildlife Management

Habitat Suitability Index Model: Red-tailed Hawk

RED-TAILED HAWK

Species Narrative

General. The red-tailed hawk (*Buteo jamaicensis*) is a fairly common to common resident in northeastern Texas (Oberholser 1974). Red-tails migrate from northern states and concentrate in areas of Texas during winter months. Commonly used habitat consists of woodlots, scattered trees, or tracks of mature woodland, often interspersed with, or adjoining large expanses of open fields. The red-tail has the widest ecological tolerance and geographic distribution of any buteo in North America (Brown and Amadon 1968). This species has not suffered the detrimental eggshell thinning observed in many other raptors due predominantly to its mammalian diet (Hickey and Anderson 1968).

Food Requirements. The red-tailed hawk is an opportunistic predator, feeding primarily on prey species which are locally common (Bohm 1978). It feeds on a variety of animals, but mostly small and medium-sized rodents, rabbits and other mammals (Brown and Amadon 1968; Imhof 1976). Other important food items include medium-sized birds, large insects and reptiles (Brown and Amadon 1968). Both adults and juveniles will feed on carrion (Errington and Breckenridge 1938).

Red-tails hunt from perches commonly overlooking open areas and by soaring above fields (Tyler and Saetveit 1969; Bohm 1978). Foraging sites in southern Michigan were open areas such as grassland and abandoned and cultivated fields (Craighead and Craighead 1956). Results from an Ohio study suggest that red-tail productivity may be partially related to the percent of hunting territory in fallow pasture (Howell *et al.* 1978). High productive sites typically had over twice as much fallow pasture (69% average) around them as low productive sites. Hunting areas in New York were recently abandoned fields with matted, grassy cover (Bart 1977). Grassland and corn stubble were equally utilized as winter foraging sites in Illinois (Schnell 1968). Plowed fields were avoided.

Water Requirements. Water does not appear to be limiting to the red-tail. Most water is supplied by the metabolic process of digesting food.

Cover Requirements. Red-tailed hawk nests are found more frequently in open woodlots and woodland edges than in closed or dense woodlots (Orians and Kuhlman 1956; Gates 1972; Misztal 1974). However, red-tail nests were found in continuously forested regions of western Maryland (Titus and Mosher In press). Low productive sites in Ohio were characterized by a greater percentage of ground cover and canopy cover as well as twice as many saplings and trees less than 15 cm (6 in) dbh (Howell et al. 1978). The average number of saplings on high and low productive sites per hectare was 2,375 and 436 respectively. Compared to random samples and surrounding habitat, red-tail hawks in Maryland were found on sites with a high percent slope, a higher number of large trees ($\geq$ 50 cm dbh), a higher shrub density, and a lower percent canopy cover (Titus and Mosher In press). Due to the availability of food (chipmunks and squirrels) in extensively forested regions, these areas probably cannot support as many redtails as more open areas characterized by a woodlot-field mix (Mosher, pers. comm.).

The average percentage of cover type(s) within a 1.2 km (0.75 mi) radius of red-tail nest sites in Alberta, over a period of 6 years, was 41% in agriculture (cultivation, pasture, forest clearing) and 34% in forest cover (McInvaille and Keith 1974). The average percentage of cover types for red-tails nesting in Ohio was 8.1% in woodland, 23.2% in crop pasture and 68.6% in fallow pasture in high productive sites; and 20.8% in woodland, 51.1% in crop pasture, 27% in fallow pasture, and 1.8% in other types in low productive sites (Howell et al. 1978).

The availability of adequate perches is vital. During non-breeding periods, red-tails commonly perch conspicuously on dead snags (Brown and Amadon 1968) and lone trees (Schnell 1968). Red-tails occasionally nest in isolated trees along fencelines and ditchbanks (Gates 1972); however, isolated trees are used mainly as hunting lookout posts.

Red-tails wintering in Iowa used open wooded areas along stream bottoms (Weller 1964). Winter perches in Illinois were in groups of trees (locations where two or more trees were within 30 m (100 ft) of each other) (Schnell 1968). All perches were in trees greater than 9 m (30 ft) tall. Ninety-six percent of observed perch sites in Michigan were 9 to 20.7 m (30 to 70 ft) high (Craighead and Craighead 1956). Both upper and mid-canopy portions of trees are used for daily activities and night roosting (Dunstan and Harrell 1973). Dense timber, particularly conifers, is frequently used as night and winter roosts (Brown and Amadon 1968).

Reproductive Requirements. Red-tail nests are generally located in mature trees, in or along the edge of woodlots and well removed from densely populated areas. The availability of suitable nesting trees are vital. The size of the tree and the height at which the nest may be placed is more important in site selection than the degree of concealment afforded by the surrounding timber (Bailey 1918). Groves used by nesting red-tails in Wisconsin were generally less than 0.4 ha (1 ac) in size (Gates 1972). Nest trees in Michigan were large, averaging 23.6 ± 3.3 m (77.8 ± 10.9 ft) tall and 52.3 ± 15.0 cm (20.9 ± 6 in) dbh. The average dbh of nest trees was 58 cm (23 in) [range 41 to 71 cm (16 to 28 in)] in southeastern Minnesota (Le Duc 1970) and 64 cm (25 in) [range 38 to 127 cm (15 to 50 in)] in Ohio (Misztal 1974). The importance (relative frequency) of any one tree species may effect nest site selection, but appears to have no direct relationship to productivity (Howell et al. 1978). Nests are often re-used year after year (Brown and Amadon 1968).

Interspersion Requirements. Territory size in Wisconsin was affected by the degree of interspersion of cover types (Peterson 1972). Red-tailed hawks in a region with a significant amount of cropland and pasture had year-round territories which averaged 119 ha (298 ac). Territories without these two cover types averaged 154 ha (384 ac). Breeding territories in southeastern South Dakota and northwestern Iowa averaged 256 ha (640 ac) (Tyler and Saetveit 1969). Craighead and Craighead (1956) reported a hunting range radius of 1.19 km (0.75 mi). The average nesting range of red-tails in southern Wisconsin was 3.75 sq km (1.5 sq mi) with a maximum diameter of 3.2 km (2 mi).

Special Considerations. The red-tailed hawk is more tolerant to civilization than most other raptor species (Jackman and Scott 1975). Nonetheless, Michigan red-tails did not nest within 370 m (411 yd) of occupied human dwellings (Belyea 1976). Nest desertion in four out of seven cases in Wisconsin was attributed to human interference (Peterson 1972).

REFERENCES CITED

Bailey, B. H. 1918. The raptorial birds of Iowa. Iowa Geol. Surv. Bull. 6:93-107.

Bart, J. 1977. Winter distribution of red-tailed hawks in central New York State. Wilson Bull. 89(4):623-628.

Belyea, G. Y. 1976. A nesting study of the red-tailed hawk in southern Michigan. Ph.D. Diss., Michigan State Univ., East Lansing.

Bohm, R. T. 1978. Observation of nest decoration and food habits of the red-tailed hawk. Loon 50(1):6-8.

Brown, L., and D. Amadon. 1968. Eagles, hawks and falcons of the world. McGraw-Hill Book Co. 945 pp.

Craighead, J. J., and F. C. Craighead, Jr. 1956. Hawks, owls, and wildlife. Dover Publ., Inc., New York. 443 pp.

Dunstan, T. C., and B. E. Harrell. 1973. Spatio-temporal relationships between breeding red-tailed hawks and great horned owls in South Dakota. Raptor Res. 7(2):49-54.

Errington, P. L., and W. J. Breckenridge. 1938. Food habits of buteo hawks in north-central United States. Wilson Bull. 50:113-121.

Gates, J. M. 1972. Red-tailed hawk population and ecology in east-central Wisconsin. Wilson Bull. 84(4):421-433.

Hickey, J. J., and D. W. Anderson. 1968. Chlorinated hydrocarbons and eggshell changes in raptorial and fish-eating birds. Science 162(3850):271-273.

Howell, J., B. Smith, J. B. Holt, Jr., and D. R. Osborne. 1978. Habitat structure and productivity in red-tailed hawks. Bird Banding 49(2):162-171.

Imhof, T. A. 1976. Alabama birds. Univ. Alabama Press, Tuscaloosa. 445 pp.

Jackman, S. M., and J. M. Scott. 1975. Red-tailed hawk (Buteo jamaicensis). Pages 68-84 In S. M. Jackman and J. M. Scott. Literature review of twenty three selected forest birds of the Pacific Northwest. Region 6. U.S.D.A. For. Serv., Region 6, Portland, Oregon.

Le Duc, P. V. 1970. The nesting ecology of some hawks and owls in southeastern Minnesota. Loon 42(2):48-62.

McInvaille, W. B., Jr., and L. B. Keith. 1974. Predator-prey relations and breeding biology of the great horned owl and red-tailed hawk in central Alberta. Can. Field-Nat. 88:1-20.

Misztal, A. 1975. The population and nesting of red-tailed hawks (Buteo jamaicensis) and great horned owls (Bubo virginianus) on the Wisconsin till plains of western Ohio. M.S. Thesis. Ohio State Univ., Columbus. Cited by Howell et al. 1978.

Mosher, J. A. Personal communication. University of Maryland, Frostburg, Maryland 21532.

Oberholser, H. C. 1974. The bird life of Texas. Univ. Texas Press, Austin. Vol. 1. 530 pp.

Orians, G., and F. Kuhlman. 1956. Red-tailed hawk and horned owl populations in Wisconsin. Condor 58:371-385.

Peterson, L. R. 1972. Biology of raptors in southern Wisconsin. Wisconsin Dept. Nat. Resour. P-R Proj. Rep. W-141-R7. 8 pp.

Schnell, G. D. 1968. Differential habitat utilization by wintering rough-legged and red-tailed hawks. Condor 70:373-377.

Titus, K., and J. A. Mosher. In press. Nest site habitat selected by woodland hawks in the central Appalachians. Appalachian Environmental Laboratory, Frostburg, Maryland. 33 pp.

Tyler, H., and P. Saetveit. 1969. The ecology of the great horned owl and the red-tailed hawk. South Dakota Bird Notes 21:77-84, 96.

Weller, M. W. 1964. Habitat utilization of two species of buteos wintering in Iowa. Iowa Bird Life 34:58-62.

Habitat Suitability Index (HSI) Model for the Red-tailed Hawk

General Information

Species Information

Species:	Red-tailed Hawk (Buteo jamaicensis)
Habitat Use Pattern:	Multicover type user
Status:	Resident
Cover Types:	Deciduous Tree Savanna (DTS), Deciduous Forested Wetland (DFW), Evergreen Shrubland (ES), Deciduous ~~Shrubland~~ (DS), Deciduous Shrub Savanna (DSS), Grassland (G), Pasture/Hayland (P/H), Forbland (F), and Cropland (C), + Deciduous Forest (D. F.) Evergreen Forest
Ecoregion:	2320 South
Model Type:	Uncalibrated Index Model

Threshold Range Size. It is estimated that at least 518 ha (1,280 ac) of suitable habitat is required to support a viable population of red-tails. If there is less than 518 ha of useable habitat available, the HSI for resident red-tails will equal 0.0.

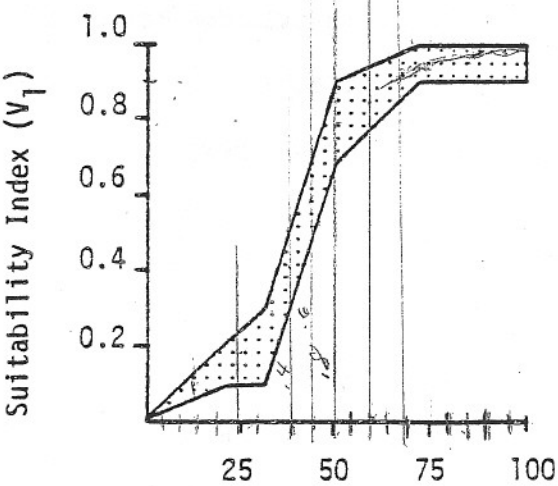
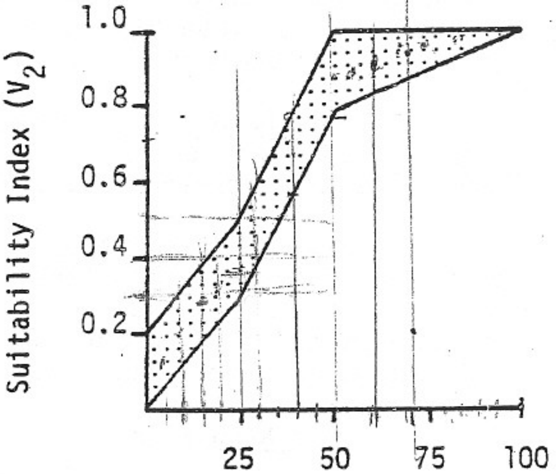
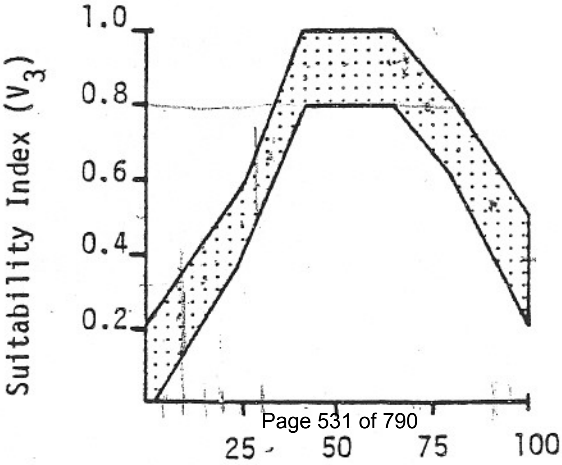
Home Range Data. The minimum home range size (Hmin) needed to support a pair of red-tails is estimated to be 1.2 km (0.75 mi) in diameter. Range size can be expanded to a maximum (Hmax) of 3.6 km (2.25 mi) in diameter.

Habitat Composition. Habitat composition information for species that are multicover type users is most useful when presented in terms of life requisite needs. Optimal life requisite composition may be determined by considering the composition of the habitat in terms of cover types and by considering what life requisites are provided by each cover type.

Life Requisite	Optimal Percentage Estimate	
Food	70-90%	Ave 80%
Cover and Reproduction	10-30%	20%

Evaluation Criteria (by cover types)

Food Value. Food value is related to the abundance and availability of suitable prey species. It is assumed that if sufficient and suitable herbaceous cover is available within the home range of the red-tail, then prey species will also be available. If large, lone trees with widely branched crowns, or groves less than 0.4 ha (1 ac) in size occur within close proximity of open feeding areas, increase the value of food accordingly. Large, lone trees will provide suitable hunting perches. Cropland and woodland will not support as many prey species suitable for red-tails and thus cannot receive a life requisite value equal to 1.0.

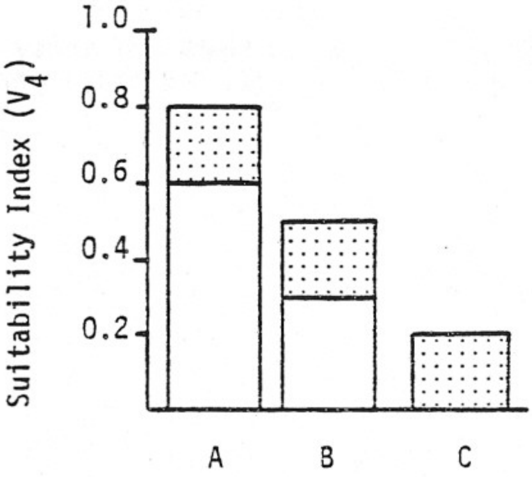
Cover Type	Variable		Suitability Index Curve
DTS, ES, DS, DSS, G, ~~P/H~~, F H/S	$[V_1]$	% herbaceous canopy cover.	
DTS, ES, DS, DSS, G, ~~P/H~~, F H/S	$[V_2]$	% of herbaceous canopy 15 to 60 cm (6 to 24 in) tall.	
DS, ES, DSS DTS	$[V_3]$	% shrub crown closure	

C [V_4] Type of crop present.

A) Grain or vegetable crops with a mature height < 0.9 m (3 ft).

B) Grain or vegetable crop with a mature height > 0.9 m (3 ft).

C) Cotton, tobacco, and other nonfood crops.



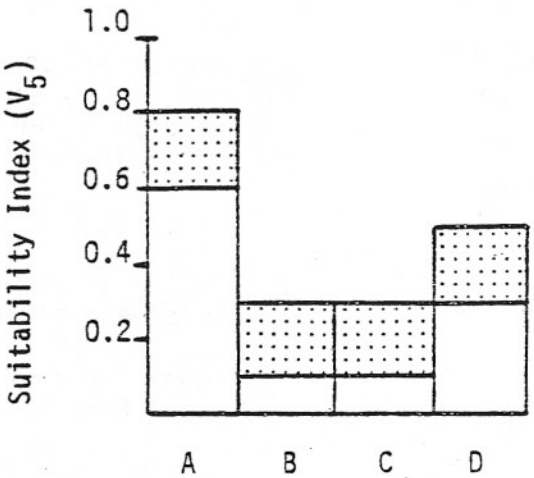
C [V_5] Type of crop management and grain availability.

A) Crop residues remain on surface, waste grain abundant.

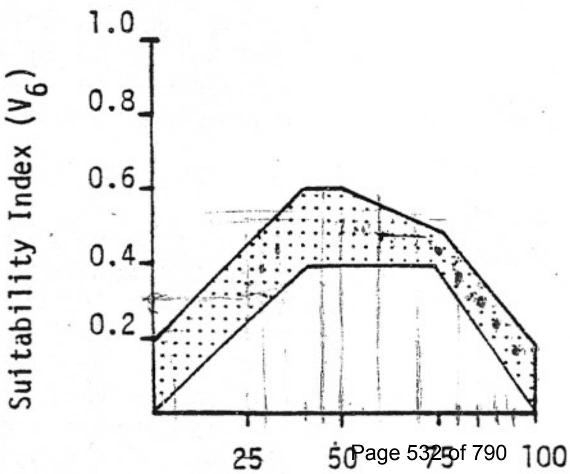
B) Crop residues remain on surface, waste grain scarce.

C) Crop residues plowed under, waste grain scarce.

D) Year-round crop production.



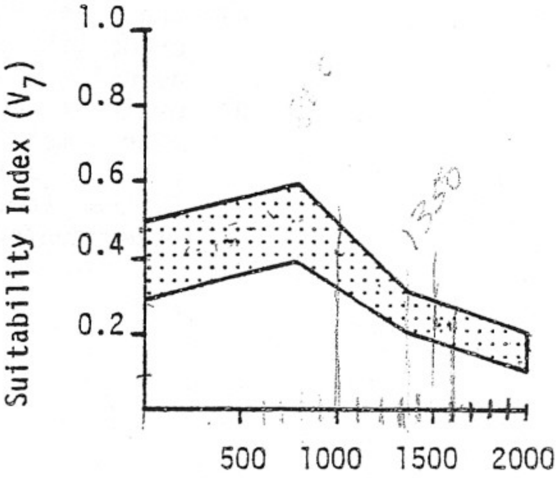
EF, DF, DFW [V_6] % canopy closure of overstory trees.



70

1350

EF, DF, DFW — $[V_7]$ Number of woody stems (> 1 m tall) per 0.4 ha (1 ac).



INIT
1 V_n
2 V_n
GEOME

Food Value in grassland, pasture/hayland, and forbland is a function of V_1 and V_2. Herbaceous vegetation that is either very short or very tall has little value to red-tails. Since V_1 and V_2 are interactive, the following function is suggested:

$$(V_1 \times V_2)^{1/2}$$

V_{10} V_n
3 V_n
ΣV_n

Food Value in deciduous tree savanna, evergreen and deciduous shrubland and deciduous shrub savanna is a function of V_1, V_2, and V_3. Since either shrubby or herbaceous vegetation can independently provide adequate support for prey species, the following function is suggested:

$$(V_1 \times V_2)^{1/2} + V_3$$

If the above function results in a value greater than 1.0, then the food value is assumed to equal 1.0.

INIT
4 V_n
5 V_n
GEOME

Food Value in cropland is a function of V_4 and V_5. Very tall crops such as corn or other grain crops will interfere with red-tail hunting whereas crop residues will supply prey with adequate food. Since these two variables are interactive, the suggested function is:

$$(V_4 \times V_5)^{1/2}$$

Food Value in evergreen forest, deciduous forest, and deciduous forested wetland is a function of V_6 and V_7. Little is known concerning hunting strategies of red-tails in wooded areas. Some understory would seem to be useful in supporting chipmunks and other ground-dwelling mammals, whereas too much woody vegetation would interfere with prey capture. Even the best of woodlands have limited food value for red-tails. Since neither V_6 nor V_7 is considered to be limiting by itself, the following function is suggested:

$\frac{27}{114.63} \times 100$

380
114.63

Food Value in cropland is a function of V_4 and V_5. Very tall crops such as corn or other grain crops will interfere with red-tail hunting whereas crop residues will supply prey with adequate food. Since these two variables are interactive, the suggested function is:

$$(V_4 \times V_5)^{1/2}$$

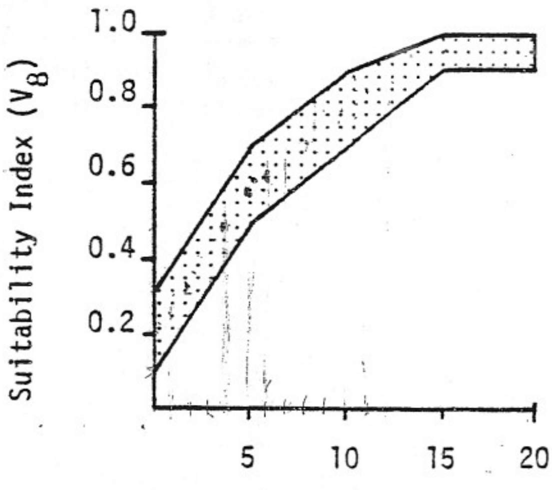
Food Value in deciduous forests, evergreen forests, and deciduous forested wetland is a function of V_6 and V_7. Little is known concerning hunting strategies of red-tails in wooded areas. Some understory would seem to be useful in supporting chipmunks and other ground dwelling mammals, whereas too much woody vegetation would interfere with prey capture. Even the best of woodlands have limited food value for red-tails. Since neither V_6 nor V_7 is considered to be limiting by itself, the following function is suggested:

INIT
6 V.
7- V.
ARITH

$$\frac{V_6 + V_7}{2}$$

Water Value. No information was available to suggest that water availability may be limiting to the red-tailed hawk.

Cover and Reproductive Value. Cover and reproductive value is related to the availability of suitable nest trees. Human disturbances may have a severe negative impact on nesting red-tails. The field user must assess each situation with respect to human interference during nesting and, if necessary, adjust the cover and reproductive value accordingly.

Cover Type	Variable		Suitability Index Curve
DF, EF, DFW, H/S	[V_8]	Number of trees $\geq$ 50 cm (20 in) dbh per 0.4 ha (1.0 ac).	

Cover and Reproductive Value in deciduous forest, evergreen forest, deciduous forested wetland, and herbland/savanna is equal to V_8. Since there is only one variable to measure, no life requisite function is needed.

HSI Determination for Multi-cover Type Users. The following is an abbreviated step by step discussion of HSI determination for multi-cover type species. More detailed information describing this process, and an example-application are included in other parts of the Handbook.

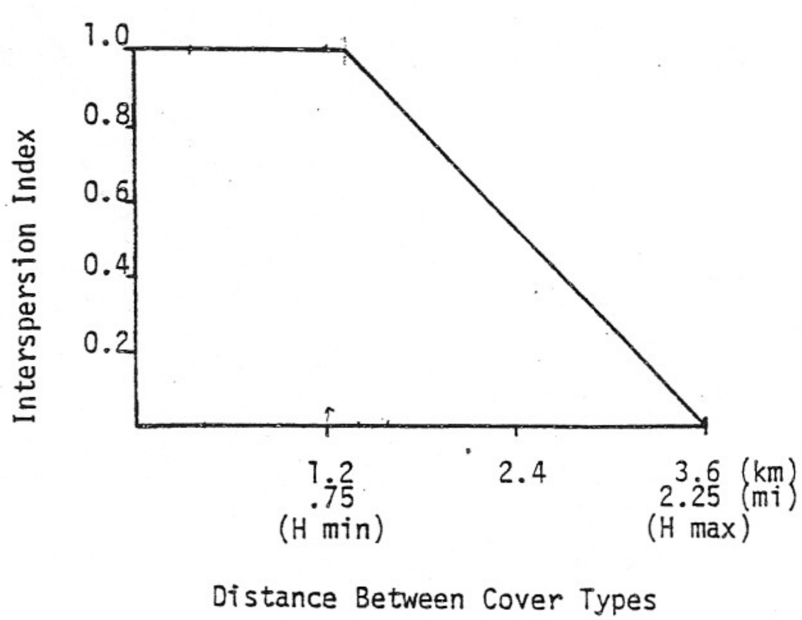
Step 1 - Determine if all life requisites can be provided considering all cover types within the study area. If any life requisites are missing, the HSI will equal zero and no further evaluation is necessary.

Step 2 - If all life requisites can be provided by existing cover types, then compute individual life requisite values for each cover type. Compute life requisite values only in the cover types indicated in the evalua-tion criteria section, using the appropriate variables and aggregation functions.

Step 3 - Using the life requisite values computed in Step 2, the next step is to determine the spatial relationship of all life requisites. Life requisite values may need to be adjusted to varying degrees depending on the distances separating them. These distances are compared with the species minimum and maximum home ranges. This step is accomplished as follows:

a) Determine the mean distances from the approximate center of each cover type missing a life requisite, to the edge of the next nearest cover type that provides the missing life requisite(s).

b) Incorporate mean distance measurement from Step a) into the x-axis of the home-range interspersion graph below. Determine where the mean distance measurement intercepts the graph, and obtain the interspersion index by reading the corresponding value from the y-axis.



c) Multiply the interspersion index for each cover type by the life requisite value(s) determined in Step 2. The product is the adjusted life requisite value.

Step 4 - Determine the relative abundance (in percent) of cover types used by the red-tailed hawk within the study area, as follows:

$$\text{Relative Area for Cover Type A} = \frac{\text{Area of Cover Type A}}{\text{Total Area of all Cover Types used by the Red-tailed Hawk}}$$

Be certain that you consider only those cover types used by the red-tailed hawk in determining this percentage.

Step 5 - Determine the % life requisite support provided by each cover type as follows:

a) For each cover type, multiply the adjusted life requisite value (Step 3) by the relative area of that cover type (Step 4).

b) Sum the products of the above multiplications for each individual life requisite, The total equals the % life requisite support.

Step 6 - Divide the % life requisite support figure (Step 5b) by the optimal % life requisite estimate provided in the General Information section of the HSI Model (use the lower percentage where a range of percents are given as estimates for optimal life requisite percent). This yields the actual life requisite value for the entire study area.

Step 7 - The Habitat Suitability Index (HSI) is the lowest of the actual life requisite values.

Model Assumptions and Limitations. It is assumed in this model that adequacy of the prey base may be estimated by measuring structural habitat characteristics assumed to be important to prey base. It is also assumed that cover value is equal to reproductive value and that water is not limiting to red-tailed hawks.

Habitat informaton originating from field investigations in various regions of the country have been used to construct the red-tail HSI model. It is assumed that the fundamental habitat requirements for various populations of the eastern race of the red-tail (B. j. borealis) will be identical. Consequently, the same evaluation criteria should be applicable for the entire eastern half of the country, classified by Bailey (1978) as the humid temperate domain.

The major limitation in this model is that optimal life requisite composition values and the interspersion graph are best estimates derived from both literature and expert opinion sources. The estimates as presented may not be valid in every situation.

Great Trinity Forest Management Plan

Wildlife Management

Wood Duck

(Aix sponsa)

Wood Duck
(*Aix sponsa*)

The wood duck is a popular and beautiful bird that inhabits forested swamps and freshwater marshes. Since the turn of the century, this species has made a remarkable recovery due the use of nest boxes, expanding beaver populations and the 1918 Migratory Bird Act. Today, the wood duck is "the second most common waterfowl species harvested in Alabama, behind mallards" (Yarrow 1999). This small to medium bird grows to about 1.5 lbs and 20 in. long and its predators include raccoons (*Procyon lotor*), turtles, snakes and herons.
(Sousa and Farmer 1983, Hepp and Bellrose 1995, Yarrow 1999)

Food

This species is an ominovore which feeds on a variety of invertebrate and vegetable matter. Vegetable matter consumed includes fruit and mast from smartweed (*Polygonum* spp.), panic grasses (*Panicum* spp.), sedges (*Cyperus* spp.), oaks (*Quercus* spp.), hickories (*Carya* spp.) and baldcypress (*Taxodium distichum*). Aquatic and terrestrial invertebrates consumed include Coleoptera, Diptera and Lepidoptera. These invertebrates are extremely important for hens during egg laying (about 80% of diet) and ducklings which depend solely on animal matter for the first 2 - 3 weeks. For drakes and fall hens, invertebrate only make up 1/3 of the diet while invertebrate make up about 50% of the diet of hens during pre- and post laying. (Sousa and Farmer 1983, Hepp and Bellrose 1995, Yarrow 1999)

Water

Water is critical for wood ducks, especially in "breeding and brood rearing habitat from mid-January to late September in the southern United States" (Sousa and Farmer 1983). Water in this area should be 7.5 - 45 cm (3 - 18 in) deep since wood ducks do not feed below 45 cm (18 in). (Sousa and Farmer 1983, Yarrow 1999)

Habitat

The wood duck is a species found in bottomland hardwood swamps and other types of wooded riparian areas. Cover of 50 - 70% is essential and may consist of shrubs or other shrub like plants that form a canopy about 2 ft above the water. Emergent plants are important since they provide seeds and harbor large numbers of invertebrates that are needed by hens and ducklings. Loafing areas such as logs and stumps are also important habitat component for wood ducks. These structures should be surrounded by water, have good visibility and be near escape cover. (Sousa and Farmer 1983, Yarrow 1999)

Reproduction

Wood ducks are cavity nesters which use abandoned woodpecker nests or naturally occurring cavities near water (particularly if it's good brood habitat). In fact, lack of suitable tree cavities have been one of the major limiting factors for this population and it can be compensated for by providing nest boxes. However, nest boxes without predator guards or plastic nest boxes are detrimental to the hen and young. Also, managers have observed high intraspecific nest parasitism in nest boxes and there is concern that such a high rate of parasitism is unnatural and may actually decrease nesting productivity. One study by Roy Nieslon et al. (2006) using genetic markers found that 85% of cavity nests were parasitized and suggested that high rates of nest parasitism is a "normal feature of wood duck breeding biology and is not just an aberration associated with nest boxes". However, these authors also suggested that while high nest parasitism rates are normal, high intensity of parasitism which results in clutches greater than 15 eggs can have adverse effects on nest productivity. Such a level of parasitism in nest boxes may be due to placing the structures in an aggregation which increases there visibility and chance that a nest will be found by another female. A study by Davis et al. (2007) found that brood survival was highest in wetlands without an aggregation of nest boxes and suggested that this placement attracted predators and that dispersing nest boxes may increase brood survival. For a tree to be a suitable cavity tree it should have a dbh between 60 - 90 cm (24 - 36 in) and the cavity should be greater than 2 m (6 ft) above the ground. The opening should be at least 7.6 by 10.0 cm (3 by 4 in) and the depth of the cavity should be 15 - 120 cm (6 - 48 in). For a cavity to be suitable it needs to be within 1 mi of water but keep in mind that the closer the cavity is to water, the better the survival rate of the ducklings. (Sousa and Farmer 1983, Hepp and Bellrose 1995, Yarrow 1999)

Breeding and Brood Rearing Habitat

This habitat is provided by a "combination of downfall and woody and herbaceous emergent plants, well interspersed with small, open water channels" (Sousa and Farmer 1983). Optimum conditions for breeding and brood habitat is 30 - 50% shrubs, 40 - 70% herbaceous emergents, 0 - 10% trees and 25% open water. Cover should be 50 - 75% of the habitat and preferably within 1m (3.3ft) of the water surface. The area should be at least 4 ha (10ac) and have 10 to 20 loafing sites per 0.4ha (1ac) and the distance to the opposite shore should be at least 30 m (100 ft). It is also important that the water is still or slow moving since breeding wood ducks and broods prefer the water current to be less than 1.6 km/hr (1 mph) and will not use the habitat if the water current is above 4.8 km/hr (3mph). (Sousa and Farmer 1983, Yarrow 1999)

Management

One limiting factor for wood duck is nest sites; therefore an area should have more than 5 potential nest sites per 0.4 ha (1 ac), with a potential nest site defined as either a nest box or suitable natural cavity. Some studies suggest that nest boxes be placed in clusters of 5 - 10 nest boxes located 15 - 30 m (50 - 100 ft) apart or clusters of 2 to 4 nest boxes per 0.4 ha (1 ac); however, other studies suggest that clustering nest boxes may increase nest parasitism and attracted predators. Another major limiting factor is predation which can be minimized by providing predator guards on nest boxes and providing 50 - 75% cover over water throughout the year. This is extremely important since predators are the primary cause of mortality of ducklings. To maximum wood duck production there should be a ratio of 5.2 brood rearing habitats to 1 nesting habitat. Distances between cover types should be less than 0.8 km (0.5 mi) and no more than 3.2km (2.0mi). Another limiting factor is food which can be maximized by protecting existing bottomland forest and marshes from draining and by using moist soil management to maximize invertebrate production, especially during the breeding season. Other beneficial activities include encouraging beaver ponds, establishing greenways along stream channels and eliminating stream channelization. (Sousa and Farmer 1983, Hepp and Bellrose 1995, Roy Nieslon et al 2006, Davis et al 2007)

Literature Cited

Davis, J.B., R.R Cox Jr., R.M. Kaminski, and B.D. Leopold. 2007. Survival of Wood Duck Ducklings and Broods in Mississippi and Alabama. Journal of Wildlife Management 71(2):507–517

Hepp, G. R., and F. C. Bellrose. 1995. Wood Duck (*Aix sponsa*). *In* The Birds of North America, No. 169 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

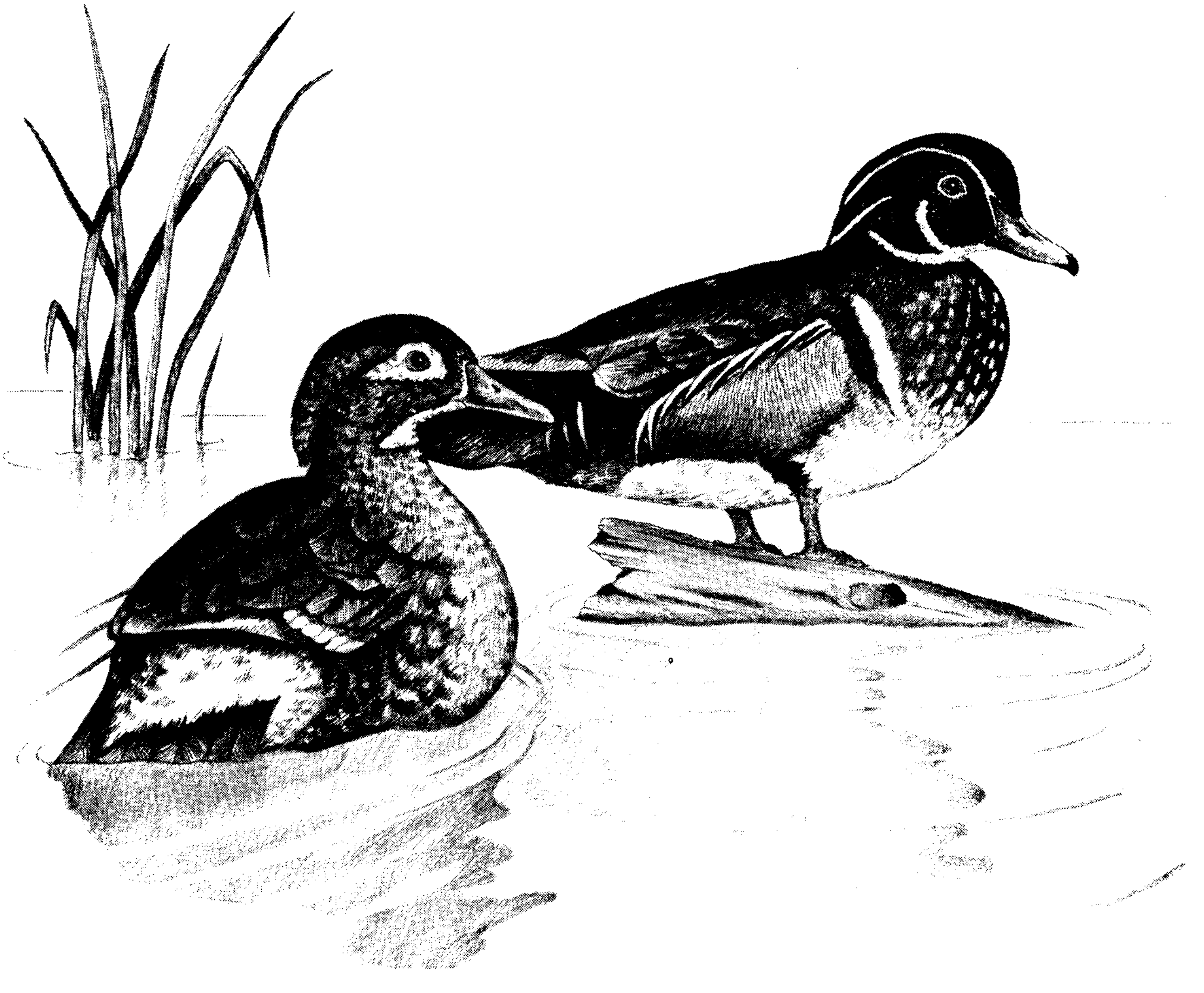
Roy Neilsen, C.L., R.J. Gates, and P.G. Parker. 2006. Intraspecific Nest Parasitism of Wood Ducks in Natural Cavities: Comparisons with Nest Boxes. Journal of Wildlife Management 70(3):835–843; 2006)

Sousa, P.J., and A.H. Farmer. 1983. Habitat Suitability Index Models: Wood Duck. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.43. 27 pp.

Yarrow, G. K. and D.T. Yarrow. 1999. Managing wildlife on private lands in Alabama and the Southeast. Alabama Wildlife Federation. Sweetwater Press, Birmingham, Alabama, USA.

FWS/OBS-82/10.43
JULY 1983

HABITAT SUITABILITY INDEX MODELS: WOOD DUCK



ı and Wildlife Service

. Department of the Interior

This model is designed to be used by the Division of Ecological Services in conjunction with the Habitat Evaluation Procedures.

FWS/OBS-82/10.43
July 1983

HABITAT SUITABILITY INDEX MODELS: WOOD DUCK

by

Patrick J. Sousa
and
Adrian H. Farmer
Habitat Evaluation Procedures Group
Western Energy and Land Use Team
U.S. Fish and Wildlife Service
Drake Creekside Building One
2627 Redwing Road
Fort Collins, CO 80526-2899

Western Energy and Land Use Team
Division of Biological Services
Research and Development
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

This report should be cited as:

Sousa, P. J., and A. H. Farmer. 1983. Habitat suitability index models: Wood duck. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.43. 27 pp.

PREFACE

This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for HSI models that follow. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model Section documents a habitat model and information pertinent to its application. The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The application information includes descriptions of the geographic ranges and seasonal application of the model, its current verification status, and a listing of model variables with recommended measurement techniques for each variable.

In essence, the model presented herein is a hypothesis of species-habitat relationships and not a statement of proven cause and effect relationships. Results of model performance tests, when available, are referenced. However, models that have demonstrated reliability in specific situations may prove unreliable in others. For this reason, feedback is encouraged from users of this model concerning improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning. Please send suggestions to:

Habitat Evaluation Procedures Group
Western Energy and Land Use Team
U.S. Fish and Wildlife Service
2627 Redwing Road
Ft. Collins, CO 80526-2899

CONTENTS

ACKNOWLEDGMENTS

Earlier versions of an HSI model for the wood duck were reviewed by Drs. Leigh Fredrickson, Frank Bellrose, and Frank McGilvrey. Dr. Fredrickson commented on two earlier drafts and his comments were very valuable in helping to describe the relationships between wood ducks and their habitat. The comments and suggestions of all three reviewers have added considerably to the quality and value of this model, and their input is very gratefully acknowledged.

The development of this HSI model was partially funded by the U.S. Army Corps of Engineers through their Waterways Experiment Station in Vicksburg, Mississippi. The participating work unit is Testing of Habitat Evaluation Methods within the Environmental Impact Research Program.

Word processing of this document was provided by Carolyn Gulzow and Dora Ibarra. The cover illustration was drawn by Jennifer Shoemaker.

WOOD DUCK (Aix sponsa)

HABITAT USE INFORMATION

General

Wood ducks (Aix sponsa) inhabit creeks, rivers, floodplain lakes, swamps, and beaver ponds (Bellrose 1976). The major breeding range of the wood duck is in the eastern United States, from Florida and east Texas north to Maine and North Dakota, and north into the eastern Canadian provinces. A Pacific population breeds from British Columbia south to California and east to Montana. The major wintering range occurs south of Maryland in the Atlantic and Gulf coast States, as well as Arkansas and Tennessee. The majority of the Pacific population winters in the Sacramento Valley. Wood ducks are permanent residents in the southern half of their breeding range.

Food

Wood ducks have been referred to as primarily herbivorous (Landers et al. 1977) although recent studies have indicated that invertebrates make up a significant part of the annual diet (Drobney and Fredrickson 1979). Wood ducks forage on the ground or in water at depths up to 46 cm (18 inches) (McGilvrey 1968). In Missouri, they foraged primarily in flooded timber during spring and fall (Drobney and Fredrickson 1979). The daily foraging radius in the southeastern United States may be as much as 40 to 48 km (25 to 30 mi) (U.S. Forest Service 1971). Food items include mast and fruits, aquatic plants and seeds, insects, and aquatic invertebrates. Acorns and other mast are important fall and winter foods (Landers et al. 1977). When acorns are lacking, other important foods include the seeds of baldcypress (Taxodium distichum), hickories (Carya spp.), buttonbush (Cephalanthus occidentalis), arrowarum (Peltandra virginica), and burreed (Sparganium spp.) (Bellrose 1976). In South Carolina, McGilvrey (1966) found that greater than 98% of the stomach contents of 108 wood ducks shot bv hunters were fruits and seeds of water oak (Quercus nigra), pin oak (Q. palustris), baldcypress, sweetgum (Liquidambar styraciflua), water hickory (C. aquatica), and corn (Zea mays). Important fall foods of wood ducks in Maine were pondweeds (Potamogeton spp.), burreeds, water bulrush (Scirpus subterminalis), oaks, and wild rice (Zizania aquatica) (Coulter 1957). Wood ducks prefer to forage for mast in areas of shallow water, although they may also forage on the forest floor (Brakhage 1966; Bellrose 1976) and even on tree limbs before the mast has fallen (Brakhage 1966). Important foods during the breeding season include persistent overwintering fruits; corn and other domestic grain; seeds and fruits from bottomland hardwood trees, shrubs, and aquatic herbaceous plants; early spring plants; and invertebrates (McGilvrey 1968).

Female wood ducks have high protein and calcium requirements in the spring and feed heavily on aquatic invertebrates (Landers et al. 1977). They satisfy their protein requirements for egg laying through their diet rather than through internal stores (Drobney 1980). Invertebrates made up about 82% by volume of the diet of wood duck hens in Missouri during the laying period (Drobney 1980). During incubation, when protein requirements were reduced, 58.5% of the diet of the hens was plant foods. Drakes did not exhibit the same pattern of invertebrate use, indicating that hens fed selectively on invertebrates during the egg laying period. The abundance and availability of macroinvertebrates to wood duck hens during the pre-breeding period is critical to successful reproduction (Fredrickson, pers. comm.). Invertebrates made up about one-third of the fall diet of drakes and hens, and the spring diet of drakes (Drobney and Fredrickson 1979).

Ducklings less than 1 week old are dependent on animal foods (primarily insects) and forage in areas where both food and some protective cover are present (Hocutt and Dimmick 1971). The diet of ducklings is similar to that of adults by 6 weeks of age.

Water

No information on dietary water needs of the wood duck was found in the literature. However, water needs are likely satisfied in wetland habitats used by the wood duck. The remainder of this section describes those water characteristics that influence habitat use by wood ducks.

Water depth affects the quantity, variety, and distribution of cover and food, and wood duck needs are generally met between the shoreline and a water depth of 1.8 m (6 ft) (McGilvrey 1968). However, even when wood ducks feed in deeper water, the actual feeding depth is generally restricted to the top 30 cm (12 inches) of water (Fredrickson, pers. comm.). Water is critical in wood duck breeding and brood-rearing habitat from mid-January to late September in the southern United States and from mid-April to late September in the northern portions of the range. Water in most of the breeding habitat should be from 7.5 to 45 cm (3 to 18 inches) deep, still or slow-moving, and sheltered from the wind. Areas with water less than 30 cm (12 inches) deep are especially important in providing invertebrate foods for breeding wood ducks (Drobney and Fredrickson 1979). A water current of 4.8 km/hr (3 mph) has been estimated as the maximum tolerable stream flow for breeding wood ducks, although broods seldom use areas with currents greater than 1.6 km/hr (1 mph) (McGilvrey 1968).

Isolated wetlands much less than 4 ha (10 acres) in size are considered marginal brood rearing habitat (McGilvrey 1968). The more shoreline per unit area of water, the more suitable the habitat, provided the distance between opposite shores is at least 30 m (100 ft).

Cover

Suitable cover for wood ducks may be provided by trees or shrubs overhanging water, flooded woody vegetation, or a combination of these two types (McGilvrey 1968). A ratio of 50 to 75% cover to 25 to 50% open water is preferred in breeding and brood rearing habitat. Adult molting habitat is similar to brood habitat (Palmer 1976), although molting adults make greater use of herbaceous wetlands dominated by cattails and bulrushes (Bellrose, pers. comm.).

An abundance of downed timber provides suitable year-round cover (Webster and McGilvrey 1966). Young trees and mature shrubs with low overhead and lateral growth provide optimal cover for breeding adults (McGilvrey 1968). Ideal shrub cover is provided by shrubs that form a dense canopy about 0.6 m (2 ft) above the water surface. The deciduous forested types used by breeding wood ducks vary throughout their range, although wooded areas that are flooded in early spring are the most suitable nesting habitat. McGilvrey (1968) lists the following as the most important habitats for nesting wood ducks: Southern floodplain forests; red maple (Acer rubrum) swamps; Central floodplain forests; temporarily flooded oak-hickory forests; and Northern bottomland hardwoods. Buttonbush is an important source of cover for wood ducks throughout much of their range (Webster and McGilvrey 1966; McGilvrey 1968).

Winter-persistent emergents that have a life form similar to shrubs, such as cattail (Typha spp.), soft rush (Juncus effusus), bulrush (Scirpus spp.), burreed, purple loosestrife (Lythrum salicaria), and phragmites (Phragmites communis), may satisfy cover requirements where more desirable shrubs and trees are not available (McGilvrey 1968).

Wood duck brood cover is provided by a combination of downfall and woody and herbaceous emergent plants, well interspersed with small, open water channels (Webster and McGilvrey 1966; Palmer 1976). In the Mississippi Alluvial Valley, broods less than 2 weeks old typically use flooded lowland forests in order to satisfy their requirements for invertebrate foods (Fredrickson, pers. comm.). Wood ducks older than 2 weeks of age use habitats dominated by buttonbush. Wood duck broods in Massachusetts preferred areas with dense cover interspersed with small open pools, clumps of buttonbush, and muskrat houses (Grice and Rogers 1965). Buttonbush clumps and muskrat houses provided loafing sites out of the water. Optimal composition in brood habitat consists of 30 to 50% shrubs, 40 to 70% herbaceous emergents, 0 to 10% trees, and 25% open water (McGilvrey 1968). Eight wood duck broods in Florida concentrated their activities in a shrub wetland community with shrub cover greater than 76%, dominated by mature Carolina willow (Salix caroliniana) (Wenner and Marion 1981). Shrubs and/or clumped herbaceous vegetation may provide cover in areas where downed timber is not available (Webster and McGilvrey 1966). South Carolina beaver ponds that provided both shrubby and herbaceous cover received greater use by wood duck broods than ponds dominated by either shrubs or herbaceous vegetation (Hepp and Hair 1977). Shrubs provide cover, security, and loafing sites, while herbaceous vegetation provides cover and habitat for invertebrates that make up a major portion of the diet of ducklings. Emergent herbaceous vegetation that does not provide any early spring cover, especially in pure stands, does not provide much suitable brood cover (Webster and McGilvrey 1966). An abundance of downed trees in shallow water [up to 0.9 m (3 ft) deep] provides excellent brood rearing cover and "...is particularly important for early broods hatching before leaves appear on trees and shrubs and before the appearance of emergent plants" (McGilvrey 1968:11).

Emergent plants used for brood cover vary with latitude but include smartweeds (Polygonum spp.), American lotus (Nelumbo lutea), pickerelweed (Pontederia cordata), bluejoint (Calamagrostis canadensis), arrowheads (Sagittaria spp.), soft rush, spatterdock (Nuphar luteum), arrowarum, and clump sedges (Carex spp.) (McGilvrey 1968). Other important herbaceous plants are water primrose (Jussiaea spp.), reed canarygrass (Phalaris arundinacea), cattail, burreed, swamp loosestrife, and grasses.

Wood duck broods and breeding pairs require loafing sites scattered throughout their habitat for preening and sunning (McGilvrey 1968). The best loafing sites are surrounded by water, have good visibility, and are near escape cover. Loafing sites should be at least 45 by 45 cm (18 by 18 inches) in size and 5 to 15 cm (2 to 6 inches) above water. Optimal habitat contains 10 to 20 loafing sites (muskrat mounds, stumps, logs, small islands, and tussocks) per 0.4 ha (1 acre). Shorelines and points of land that are relatively bare of vegetation are marginal substitutes for more optimal loafing sites. The lack of suitable loafing sites may be a limiting factor in brood use (Beard 1964).

Wood duck broods in South Carolina used small ponds (0.03 to 0.50 ha; 0.07 to 1.2 acres) significantly more often than larger ponds (1.51 to 3.80 ha; 3.7 to 9.4 acres) (Hepp and Hair 1977).

Shrub swamps dominated by buttonbush were preferred as fall roost sites in southern Illinois over flooded forested habitats and open water (Parr et al. 1979). One such roost of 200 ha (494 acres) consisted of 60% buttonbush cover and 40% open water. Another fall roost site was dominated by American lotus, and another one was dominated by water willow (Decodon verticillatus).

Ideal winter habitat consists of a complex of wetlands centered on a permanent wetland (Fredrickson, pers. comm.). Optimum winter habitat includes scrub/shrub wetlands, emergent wetlands, dead timber, and flooded forests.

Reproduction

The distribution of breeding populations of wood ducks is closely related to "... bottomland hardwood forest with trees of sufficient size to contain usable nest cavities and water areas that satisfy food and cover requirements" (McGilvrey 1968:3). Important limiting factors include the availability of suitable nesting cavities (McGilvrey 1968), and the availability of protein foods for pre-breeding females (Fredrickson, pers. comm). Hens are most easily able to satisfy their protein requirements in flooded lowland forests, where flooding dynamics create a highly productive invertebrate food base. In the Mississippi Alluvial Valley, 1 ha (2.47 acres) of properly flooded forest can provide enough protein foods to support 800 wood ducks for 1 day (Fredrickson, pers. comm.). If it is assumed that a hen will use a flooded forest habitat for 60 days during the pre-breeding and nesting periods, then 1 ha (2.47 acres) of properly flooded forest can support about 13 hens (or 5 hens/0.4 ha [1.0 acre]) during the 60-day use period. A ratio of 8 ha (20 acres) of nesting habitat to every 0.4 ha (1 acre) of brood habitat is recommended for maximum production in areas where natural cavities provide the only potential nest sites (McGilvrey 1968). However, this ratio is based on: (1) the presence of at least 1 suitable cavity/Z ha (5 acres); and (2) the carrying capacity of each 0.4 ha (1.0 acre) of brood habitat being sufficient to accommodate broods produced by four nest cavities.

The closer the nest cavity to water, particularly to suitable brood habitat, the better (McGilvrey 1968). Cavities in trees in or near the water are preferred. Most wood duck nests in tree cavities in Massachusetts were located within 183 m (ZOO yds) of water (Grice and Rogers 1965). Wood ducks nesting in tree cavities in Minnesota selected cavities that were significantly closer to water and to canopy openings than were randomly sampled trees (Gilmer et al. 1978). Nest trees ranged from 0 to 350 m (0 to 383 yds) from water and averaged 80 m (87.5 yds). Twenty-one of 31 nest trees selected by radio-marked hens were within 0.5 km (0.31 mi) of permanent water, while eight nests were farther than 1.0 km (0.62 mi) from permanent water. Artificial nest sites in wooded areas are best located within 0.4 km (0.25 mi) of water, but nest boxes located up to 1.6 km (1 mi) from water may also receive use (Bellrose 1976). Nest boxes placed within 1.4 km (0.86 mi) of brood habitat in a Florida study area received significantly greater use than those placed further away (Wenner and Marion 1981).

Wood ducks generally nest in tree species that have a mature size of at least 35 to 40 cm (14 to 16 inches) dbh and a long life expectancy (Hansen 1966). The minimum-sized tree used for nesting in Minnesota was 28 cm (11 inches) dbh (Gilmer et al. 1978). Overmature and decadent trees usually contain the largest number of suitable cavities (McGilvrey 1968). Conifers (Hansen 1966) and dead trees, other than cypress, rarely provide suitable cavities (McGilvrey 1968). The most suitable cavity trees range from 60 to 90 cm (24 to 36 inches) dbh. Natural cavities used for nesting by wood ducks in Massachusetts ranged from 33.0 to 91.4 cm (13 to 36 inches) dbh, with a mean dbh of 68.6 cm (27 inches) (Grice and Rogers 1965).

Acceptable nest cavities in trees are at least 2 m (6 ft) above ground, have an entrance size of 9 to 30.5 cm (3.5 to 12 inches) in diameter, and a depth of 15 to 120 cm (6 to 48 inches) (McGilvrey 1968). Bellrose (pers. comm.) considered the minimum entrance dimensions to be 7.6 by 10.0 cm (3.0 by 4.0 inches); smaller entrances restrict many wood ducks. Optimal tree cavities, according to McGilvrey (1968) have an entrance size of 10 cm (4 inches) in diameter, a diameter at the bottom of 25 to 27.5 cm (10 to 11 inches), a cavity depth of 60 cm (24 inches), and are 6 to 15 m (20 to 50 ft) above ground. Fredrickson (pers. comm.) suggested that the optimum cavity height of 6 to 15 m, as defined by McGilvrey (1968), is simply where most suitable cavities form in trees rather than an expressed preference by nesting wood ducks. However, Bellrose et al. (1964) found an increasing index of use (i.e., use compared to availability) with increasing cavity height. A suitable cavity must drain well and preferably has its entrance protected from the weather (McGilvrey 1968). Cavity trees in southeastern Missouri were defined as all trees at least 24.1 cm (9.5 inches) dbh that contained at least one cavity with an entrance size of at least 6.4 by 8.9 cm (2.5 by 3.5 inches) (Weier 1966). Suitable cavities were those of adequate dimensions that did not have adverse features, such as water or excessive debris in the cavity or open tops above the cavity. A total of 109 cavity trees were found in three cover types, and 17 were judged to contain suitable cavities for wood ducks, a ratio of 1 suitable cavity to 6.4 cavity trees. A suitable cavity on two study areas in Massachusetts was defined as having a minimum entrance size of 6.4 by 8.9 cm (2.5 by 3.5 inches) and being within 0.8 km (0.5 mi) of water (Grice and Rogers 1965). Results were 1 suitable cavity/5.3 cavity trees (13 suitable out of 69 cavities) on one study area and 1 suitable cavity/4 cavity trees (9 suitable out of 36 cavities) on the second area.

The density of suitable cavities on two Massachusetts study areas was 2.5/2.59 km^2 (1 mi^2) and 0.6/2.59 km^2 (1 mi^2), although the estimates were based on total study area size rather than on timbered area only (Grice and Rogers 1965). The density of suitable cavities in timbered bottomland in Iowa was 1/9.7 ha (24 acres) (Dreis and Hendrickson 1952, cited by Grice and Rogers 1965). In Illinois, suitable cavities were defined as those with an entrance diameter of at least 8.9 cm (3.5 inches) and that were free of water or debris (Bellrose et al. 1964). One suitable cavity/5.3 ha (13 acres) was found in bottomland forests, and 1 suitable cavity/2.0 ha (5 acres) was found in upland woodlots. The density of suitable cavities (defined above) in three timber types in Missouri ranged from 1/1.4 ha (3.4 acres) to 1/4.2 ha (10.3 acres), and averaged 1/2.1 ha (5.2 acres) of forested habitat (Weier 1966). The highest reported density of suitable cavities [defined by an entrance diameter of at least 10 cm (3.9 inches)] was 4/ha (1.6/acre) in mature northern hardwood and mature aspen forests in Minnesota (Gilmer et al. 1978).

Interspersion

The best wood duck habitat is characterized by nest sites in close proximity to brood habitat (McGilvrey 1968). However, wood duck broods in North Carolina moved 2.4 km (1.5 mi) from a nesting pond to a shrub thicket marsh for brood rearing (Hardister et al. 1962). Although most of the movement was along a water course, overland travel of 0.16 km (0.1 mi) was required from the nesting pond to the river used for the major part of the movement. Wood duck hens and broods in Minnesota travelled overland up to 3.9 km (2.4 mi) from nest site to brood habitat (Ball 1973, cited by Gilmer et al. 1978). Wood duck broods in eastcentral Texas moved up to 11.7 km (7.7 mi) to brood habitat from nest sites located in areas without brood habitat, although overall brood survival was only 8% (Ridlehuber 1980). Management of forests for wood duck nesting cavities greater than 0.8 km (0.5 mi) from brood habitat is generally not recommended (McGilvrey 1968). Ball et al. (1975:778) found "... a significant negative linear correlation . . . between distance of overland moves completed prior to 2 weeks of age and number of surviving ducklings in broods of radio-marked hens" (21 wood duck hens, 8 mallard [*Anas platyrhyncos*] hens). Broods that moved less than 0.8 km (0.5 mi) averaged 8.5 ducklings compared to an average of 6.8 ducklings in broods that moved greater distances. The maximum reported brood density is 17 broods on a 5.7 ha (14 acres) impoundment in Maryland (McGilvrey n.d., cited by McGilvrey 1968). In North Carolina, a 16.2 ha (40 acres) brood-rearing area supported a minimum of 27 wood duck broods in 1966 and 17 broods in 1967 (Vance 1968). Also in North Carolina, duckling density averaged about 2.0/0.4 ha (1.0 acre) of suitable brood rearing habitat and ranged from 1.6 to 2.3 ducklings/0.4 ha (1.0 acre) (Baines 1971).

McGilvrey (1969) reported a survival rate of hatched ducklings to flight stage of 53% (9.8 ducklings/brood at hatch; 5.2 ducklings/brood reaching flight stage). Ball et al. (1975) accounted for the loss of total broods, and concluded that wood duck hens successfully raised 41% of the total ducklings hatched.

Wood ducks do not maintain stable home ranges, and both the size and shape of their home ranges are flexible (Bellrose 1976). The total home range utilized by broods in South Carolina varied from 0.77 to 29.6 ha (1.9 to 73.1 acres) (Hepp and Hair 1977). Movements from fall roosts in Illinois ranged up to 10 km (6.2 mi), although most movements were within 2.2 km (1.4 mi) of the roosts (Parr et al. 1979). Areas of activity during the fall ranged from 23.9 to 186.2 ha (59 to 460 acres) and averaged 90.6 ha (224 acres). Most activity of nesting hens in Minnesota was within 1.0 km (0.6 mi) of the nest site, suggesting that a pair may use an area of approximately 3.0 km^2 (1.6 mi^2) (Gilmer et al. 1978).

Special Considerations

In areas where natural cavities are lacking or limiting, artificial nest boxes can be used to increase breeding populations (Bellrose et al. 1964). The most important factors limiting wood duck breeding populations are availability of and competition for suitable cavities, predators (McGilvrey 1968), and food (Fredrickson, pers. comm.). A nest box program that provides predator-proof nesting cavities can minimize the effects of the first two of these factors. In Massachusetts, Grice and Rogers (1965) found strong evidence that natural nest cavities were in short supply and concluded that (p. 87) " wood ducks can be maintained at a higher level of abundance with [nest boxes] than without them". Other studies have also reported increases in breeding populations due to the use of nest boxes (Bellrose et al. 1964; Jones and Leopold 1967; Strange et al. 1971; Alexander 1977). However, some evidence exists to suggest that an excessive number of nest boxes may be detrimental to wood duck production. In California, a breeding population of wood ducks increased faster than the number of available nest sites (Jones and Leopold 1967). Over the course of the 9-year study, nest sites were gradually increased from 3 to 16 on a 11.3 ha (28 acres) marsh; an increase of breeding pairs from 3 to 35-40 occurred during the same period. At the higher levels of pair density, the population became essentially self-limiting due to intraspecific competition for nest cavities, an increase in nest desertion and dump nesting (i.e., instances in which several hens lay eggs in the same nest site), and a resultant decrease in the production of young per pair. Nest interference is also common on sites with extensive habitat where food is abundant and nest sites are limited (Fredrickson, pers. comm.). However, several researchers have reported that dump-nesting resulted in a greater production of young (Morse and Wight 1969; Clawson et al. 1979; Heusmann et al. 1980). Strader et al. (1978) cautioned that crowded nesting conditions could be detrimental to wood duck production; they observed a wood duck hen call a brood from an adjacent nest box mounted on the same support pole and abandon incubation of her own clutch.

McGilvrey (1968) recommended that nest boxes be placed in clusters of 5 to 10 spaced 15 to 30 m (50 to 100 ft) apart within clusters. Bellrose (1976) recommended that nest boxes be placed in groups of 2 to 4/0.4 ha (1.0 acre). Bellrose et al. (1964) recommended a nest box density of 2 to 3/0.4 ha (1.0 acre) in "high-quality habitat", although criteria to determine high-quality habitat were not presented. This level of nest boxes was recommended for woodlots where nesting in natural cavities was 1 pair/4.0 ha (10 acres). Additional guidelines for nest box placement are available in Bellrose et al. (1964), Bellrose (1976), and McGilvrey (1968). None of these references, however, contain information on a possible saturation level of nest boxes beyond which production would either remain constant or decrease. All of the above references note that nest boxes are effective only if they are predator-proof and regularly maintained.

Clearing of bottomland hardwoods has adversely affected wood duck populations because bottomland hardwood sites provide habitat for nesting, brood rearing, and wintering (Bellrose 1976).

HABITAT SUITABILITY INDEX (HSI) MODELS

Model Applicability

Geographic area. The two HSI models contained here have been developed for application within the breeding and wintering range of the wood duck (Fig. 1).

Season. These HSI models may be used to evaluate breeding (spring and summer) habitat and/or winter (fall and winter) habitat, depending on the residency status of the wood duck in the area to be evaluated.

Cover types. These models may be used to evaluate habitat in the following cover types (terminology follows that of U.S. Fish and Wildlife Service 1981): Deciduous Forest (DF); Deciduous Forested Wetland (DFW); Deciduous Scrub-Shrub Wetland (DSW); Herbaceous Wetland (HW); and Riverine (R). Use of unflooded deciduous forests is restricted to the breeding season model and should not be included when using the winter habitat model; however, flooded lowland deciduous forests should be included as winter habitat. Evaluation of wetlands should be restricted to those with water present during either the nesting/brood-rearing period or during the winter period, depending on the model(s) being used.

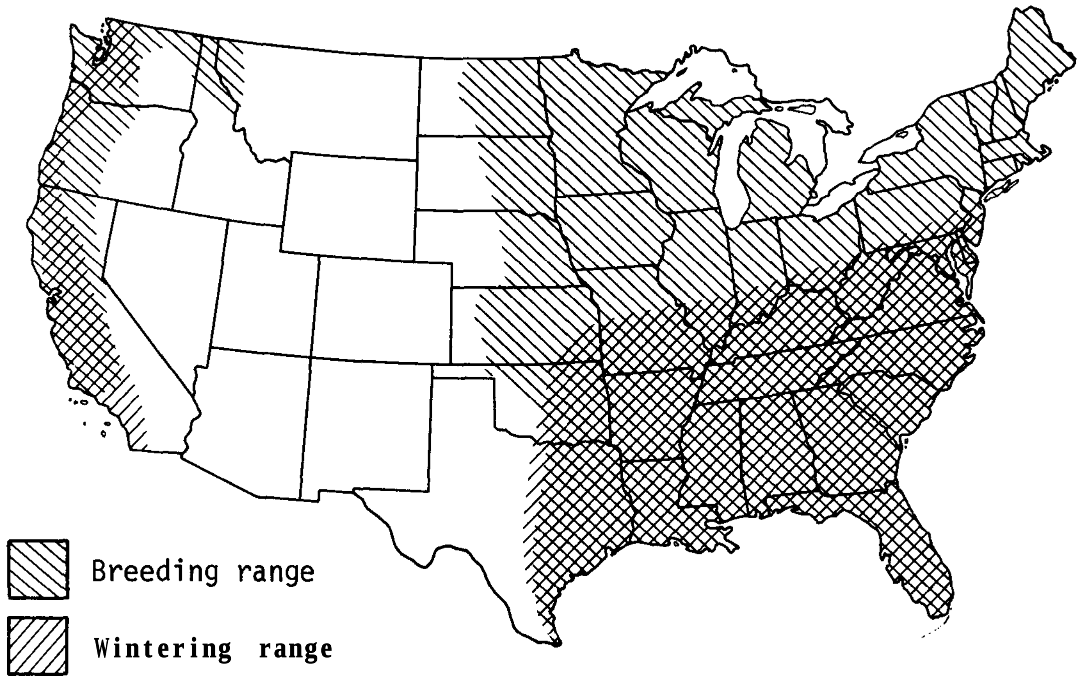


Figure 1. Geographic applicability of the wood duck HSI models within the United States (ranges from Bellrose 1976).

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before an area will be occupied by a species. The minimum habitat area for broods is estimated to be 4 ha (10 acres) of any of the wetland cover types listed above. Potential brood habitat may exist either as an isolated wetland of at least 4 ha or as smaller wetlands separated by less than 46 m (50 yds) of land where the total area of potential brood habitat equals at least 4 ha. In stream or riverine habitat, small brood units should be within 0.4 km (0.25 mi) of each other. Minimum habitat area for habitat components other than brood habitat is unknown.

Verification level. These models have not been tested against habitats of known quality. Earlier drafts were reviewed by Drs. Leigh Fredrickson, Frank Bellrose, and Frank McGilvrey. Their review comments have been incorporated into the models.

Model Description - Breeding

Overview. The breeding season HSI model for the wood duck considers nesting and brood-rearing needs as critical components of breeding habitat. An HSI value for the breeding season considers the quality, composition, and juxtaposition of nesting and brood rearing resources. Food (vegetable and invertebrate) is considered to be correlated with vegetative cover, and the variable used to evaluate brood cover in this model is assumed to serve as a surrogate measure of food suitability. Factors other than vegetative cover (e.g., water quality, current, depth, permanence) may affect food suitability for wood ducks, but are not included in this model due to the difficulty of establishing relationships between the variables and a measure of food suitability. This is particularly difficult for highly dynamic variables, such as flooding periodicity. The assumption that food suitability can be estimated by considering vegetative cover only is the major limitation of this model.

The following sections identify important habitat variables, describe suitability levels of the variables, and describe the relationships between variables. The relationship between habitat variables, life requisites, and cover types used in this model and an HSI value for the wood duck during the breeding season is shown in Figure 2.

Nesting component. The quality of nesting habitat is a function of the availability of nesting sites. Potential nesting sites may be either naturally occurring tree cavities or artificial nest sites in the form of nest boxes. However, the presence of natural (including those in live trees and snags) and/or artificial nest cavities does not guarantee an equivalent number of successful nests. The proportion of observed potential nesting sites that are actually suitable for wood duck nesting and the proportion of suitable nesting sites that can be expected to support successful nests are important criteria determining the number of ducklings produced in a specified area.

Grice and Rogers (1965) tallied all cavities on two study areas but defined as suitable those cavities with minimum entrance dimensions of 6.4 by 8.9 cm (2.5 by 3.5 inches) and that were located within 0.8 km (0.5 mi) of water. Only 22 of 105 cavities (20.9%) met the minimum criteria. Weier (1966) tallied all cavities within 0.8 km (0.5 mi) of water that had a minimum entrance dimension of 6.4 by 8.9 cm (2.5 by 3.5 inches), a nesting platform of at least 12.7 by 17.8 cm (5 by 7 inches), and that were located in trees with a minimum dbh of 24 cm (9.5 inches). Suitable cavities met those criteria, did not contain water or debris, and were not open-topped. Seventeen of 109 cavities (15.6%) meeting minimum criteria were classed as suitable. In order to most easily evaluate natural cavities with this model, it is assumed that a cavity is potentially useful if it has a minimum entrance size of 7.6 by 10.0 cm (3.0 by 4.0 inches) (Bellrose, pers. comm.). Based on the information presented above, it is also assumed that only 18% of observed cavities meeting this minimum criterion will actually be suitable for wood duck use. All artificial nest sites are assumed to be suitable if they are predator-proof and cleaned and repaired annually.

The second major criterion determining the number of successful nests on a given area is the proportion of suitable cavities that can be expected to produce successful nests. Bellrose et al. (1964) found that of 631 natural cavities available and structurally suitable (i.e., minimum entrance dimensions as described above and free of water or debris), 235 (37%) were used by wood ducks. Data from numerous studies summarized by Bellrose (1976) indicate that the average use of artificial nest sites is 41% (46,761 house years; 19,108 nests). However, these data for both natural and artificial sites do not take into account whether factors other than the availability of nest sites were limiting the nesting population; for example, poor quality brood-rearing

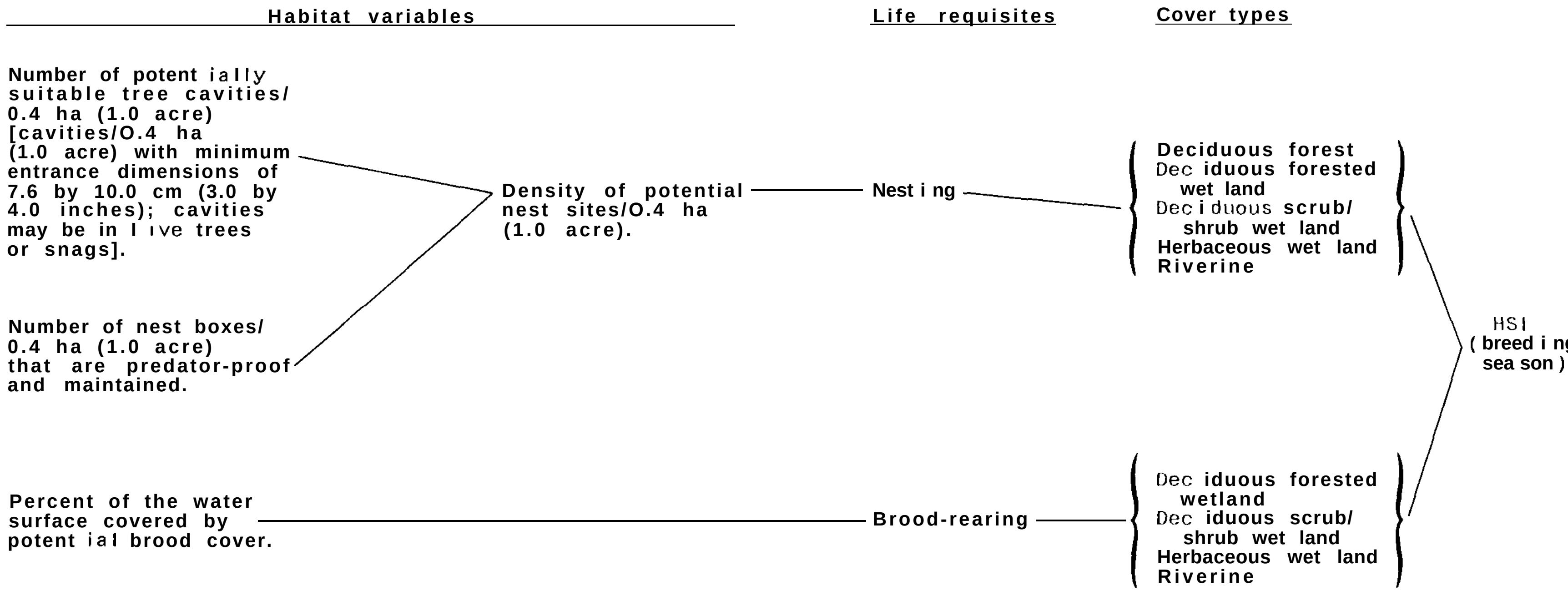


Figure 2. The relationship of habitat variables, life requisites, and cover types to an HSI value for the wood duck during the breeding season.

habitat may have limited recruitment of hens into the breeding population, or poor pre-breeding habitat may have limited the number of hens able to successfully nest. For the purposes of this model, it is assumed that all potential nest sites meeting the minimum criteria defined above may potentially be used.

If it is assumed that all suitable natural and artificial nest sites may potentially be used, then the success rate of the initiated clutches will determine the overall production of young from nest sites. The success rate of nests in natural cavities in Illinois was 49.1% (118 nests, 58 successful) from 1939-1940 and 39.9% (158 nests, 68 successful) from 1958-1961, with the lower success rate due to an increase in predation (Bellrose et al. 1964). However, the highest success rate in natural cavities reported in the literature is 52% (Prince 1965, cited by Bellrose 1976). It is assumed in this model that 52% is the best success rate that can be expected for wood ducks nesting in natural cavities.

Bellrose (1976) summarized the results of a number of studies of artificial nest sites for wood ducks. The average success rate, with individual success rates weighted by the number of nests, was 71.6%. However, the two highest reported success rates for wood ducks nesting in artificial cavities are 95%, based on 341 nests in Arkansas (Brown 1973, cited by Bellrose 1976), and 94%, based on 281 nests in Iowa (Leopold 1966, cited by Bellrose 1976). Based on this information, it is assumed in this model that 95% is the best success rate that can be expected for wood ducks nesting in nest boxes.

Based on the preceding discussion, the number of successful nests that can be expected on a given area can be determined by the following equation:

$$\text{\# of potentially successful nests} = (NT \times P1_T \times P2_T) + (NB \times P1_B \times P2_B) \quad (1)$$

where: NT = the number of tree cavities with a minimum entrance size of 7.6 by 10.0 cm

$P1_T$ = the proportion of observed tree cavities that can be expected to be suitable for nesting by wood ducks

$P2_T$ = the proportion of suitable cavities that can be expected to produce successful nests

NB = the number of available nest boxes

$P1_B$ = the proportion of nest boxes that are actually suitable for nesting by wood ducks

$P2_B$ = the proportion of suitable nest boxes that can be expected to produce successful nests

Substituting the values determined previously for $P1_T$, $P2_T$, $P1_B$, and $P2_B$ yields the following equation:

$$\begin{aligned}\#\text{ of potential successful nests} &= (NT \times .18 \times .52) + (NB \times 1.0 \times .95)\\ &= (NT \times .09) + (NB \times .95) \qquad (2)\end{aligned}$$

The maximum reported density of successful nests appears to be about 5 successful nests/0.4 ha (1.0 acre) on a North Carolina study area (Hester n.d., cited by McGilvrey 1968). Although this may not represent a stable maximum density (Bellrose, pers. comm.), it is assumed in this model that 5 successful nests/0.4 ha (1.0 acre) represents the maximum density of successful nests and therefore determines the maximum production of ducklings. Based on equation (2), this maximum density can be achieved with either 55.6 natural cavities/0.4 ha (1.0 acre) or 5.3 nest boxes/0.4 ha (1.0 acre), or by a combination of the two types of nest sites. However, this nest site density does not necessarily need to exist across an entire study area in order to have optimal habitat. The relationship between optimal nesting habitat and optimal brood-rearing habitat is discussed under the Interspersion Component section. Although some evidence exists to suggest that wood duck nesting populations can be so dense that overall production is adversely affected (Jones and Leopold 1967; Strader et al. 1978), such a relationship has not been documented to the point that a decrease in habitat suitability beyond a certain density of nesting sites can be predicted.

Brood-rearing component. The quality of brood-rearing habitat is influenced by cover, water permanence, and wetland characteristics.

Cover for wood duck broods consists of dense cover in shallow wetlands with water present throughout the period of brood occupancy. Cover can be provided by emergent herbaceous vegetation, emergent shrubs and trees with crowns within 1 m (3.3 ft) of the water surface, or woody downfall. Dense cover that is well interspersed with small open water channels provides optimal brood habitat. Optimal brood cover within a wetland is assumed to occur when the proportion of total cover in the wetland ranges from 50 to 75 %. Other factors that influence the suitability of brood habitat include water depth, quality, current, and permanence. All of these factors influence the amount of cover and the macroinvertebrate food base to a certain extent and may be highly dynamic within a wetland. It is assumed in this model that cover conditions are the reflection of the combined influence of these variables. It is assumed, therefore, that the quality of wood duck brood habitat can be evaluated solely on the basis of the amount of cover available in the wetland. A major implication of this assumption is that the abundance and quality of vegetative and invertebrate foods is indicated by the cover conditions described above. This assumed relationship may not be valid in all conditions, especially in flooded lowland forests, where an abundant detrital-based food source may be present in the absence of low, dense cover.

Interspersion component. Nesting and brood-rearing needs can be met by different cover types, and a consideration of the juxtaposition and composition of cover types providing the life requisites is necessary in order to evaluate breeding habitat suitability.

Habitat suitability is influenced by the juxtaposition of nesting and brood-rearing habitat. Optimal juxtaposition of nesting and brood-rearing resources is assumed to exist when cover types providing these life requisites are located within 0.8 km (0.5 mi) of each other. When potential nesting and brood-rearing habitats are separated by more than 3.2 km (2 mi) of upland habitats with no aquatic "travel lanes", it is assumed that the cover types are too far apart to be used by wood ducks or that mortality of ducklings travelling from the nest to brood-rearing habitat will equal 100%.

Habitat suitability is also influenced by the proportion of habitat (composition) providing nesting and brood-rearing resources. In order to determine the optimal composition of nesting and brood-rearing habitat, it is necessary to determine the number of young capable of reaching flight stage per unit area of optimal brood-rearing habitat compared to the number of young produced per unit area of optimal nesting habitat. The maximum reported density of broods is 17 broods on a 5.7 ha (14 acres) impoundment in Maryland, equivalent to 1.2 broods/0.4 ha (1.0 acre) (McGilvrey n.d., cited by McGilvrey 1968). The observed broods on a 54.7 ha (135 acres) area, including the 5.7 ha impoundment, averaged 9.8 ducklings at hatching and 5.2 ducklings reaching flight stage, a survival rate of 53% (McGilvrey 1969). The 5.7 ha impoundment, therefore, supported about 88 ducklings (i.e., 17 broods x 5.2 ducklings/brood) to flight stage, an average of 6.2 ducklings/0.4 ha (1.0 acre) of brood-rearing habitat. This level of production is considered to be the potential of optimal brood-rearing habitat for the purposes of this model.

Optimal nesting habitat was described earlier as capable of producing 5 successful nests/0.4 ha (1.0 acre). If the average clutch size in normal nests is assumed to be 12.2 (Bellrose 1976) and all eggs are assumed to hatch successfully, then 0.4 ha (1.0 acre) of optimum nesting habitat can potentially produce 61 ducklings (i.e., 12.2 ducklings/clutch x 5 clutches/0.4 ha) leaving the nest sites. The highest survival rate of ducklings reported in the literature is 53% (McGilvrey 1969). It is assumed in this model that this is the optimal survival rate of ducklings reaching brood-rearing habitat. If it is further assumed that survival from the nest to brood-rearing habitat equals 100% (i.e., interspersion is optimal), and optimal brood-rearing habitat exists, then an average of 32.3 ducklings (0.53 x 61) will survive to flight stage from the 61 ducklings produced on 0.4 ha (1.0 acre) of optimal nesting habitat. As described above, 0.4 ha (1.0 acre) of optimum brood-rearing habitat can potentially support 6.2 ducklings to flight stage. Therefore, the ratio of optimum brood-rearing habitat to optimum nesting habitat to support maximum wood duck production is approximately 5.2:1 (i.e., 32.3/6.2 = 5.2). The maximum potential production of wood ducks per unit area will occur if optimal nesting and optimal brood-rearing conditions exist on all areas under consideration. Therefore, the optimal composition of wood duck habitat is approximately 19% optimal nesting habitat ([1/5.2] x 100 = 19%) and 100% optimal brood-rearing habitat ([5.2/5.2] x 100 = 100%).

The assumptions involved in determining optimal composition of nesting and brood-rearing resources are summarized below:

1. Optimal nesting habitat will produce 5 successful nests/0.4 ha (1.0 acre).

2. Average clutch size in normal nests (i.e., non-dump nests) is 12.2, and hatching success equals 100%.

3. Survival of ducklings from nests to brood-rearing habitat equals 100%, and survival to flight stage of ducklings reaching brood-rearing habitat equals 53%.

4. Optimal brood-rearing habitat can support 6.2 ducklings/0.4 ha (1.0 acre) to flight stage.

5. Optimal habitat conditions for wood duck production consist of nesting habitat and brood-rearing habitat provided by the same cover types (i.e., all cover types provide both nesting and brood-rearing habitat).

Model Description - Winter

Overview. This winter HSI model for the wood duck considers cover as the key life requisite determining winter habitat suitability. The measurement of vegetative cover within wetlands is assumed to serve as a surrogate measure of winter food suitability. Other factors affect food suitability, but are not included in this model. The assumption that a measure of vegetative cover can be used to evaluate food suitability is a limitation of the model. The assumption may not be valid in some situations, such as when wood ducks are feeding in flooded bottomland forests, where food may be abundant in the absence of low vegetative cover. The relationship between habitat variables, winter cover, cover types, and an HSI for winter habitat of the wood duck is shown in Figure 3.

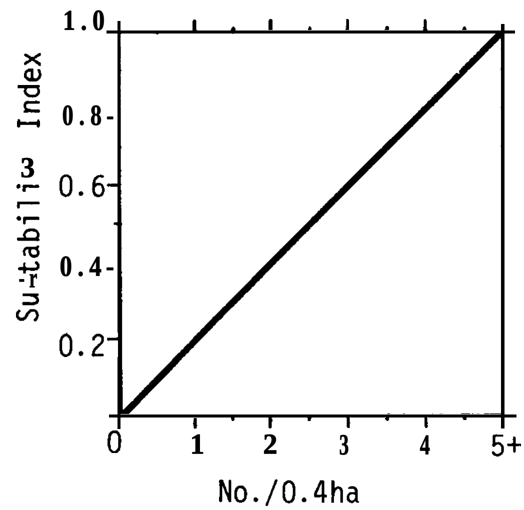
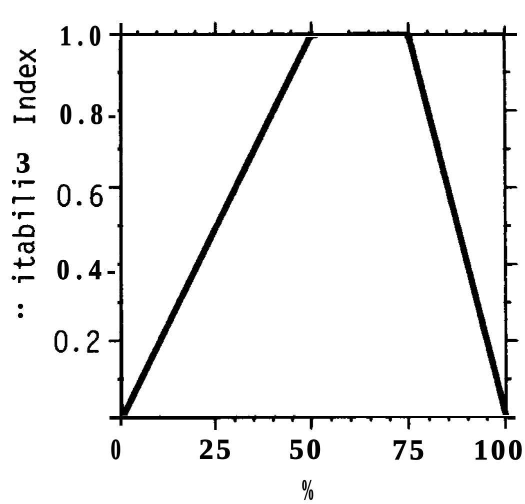
Habitat variable	Life requisites	Cover types	
Percent of the water surface covered by potential winter cover	Cover	Deciduous forested wetland Deciduous scrub/shrub wetland Herbaceous wetland Riverine	HSI (winter)

Figure 3. The relationship of habitat variables, life requisites, and cover types to an HSI value for the wood duck during the winter.

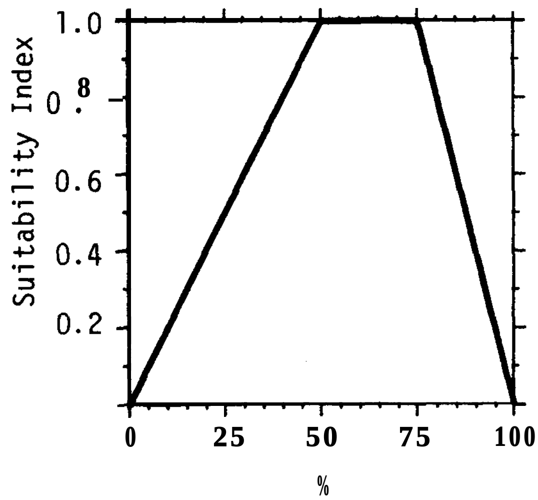
Cover component. It is assumed in this model that winter habitat needs of the wood duck are similar to habitat used during the brood-rearing period (see p. 13). Optimal conditions are assumed to be present if the amount of total cover (woody and/or herbaceous) ranges from SO-75%. Winter-persistent herbaceous plants are the only type of herbaceous vegetation considered in an evaluation of winter habitat. Water depth, quality, current, and permanence are not treated as separate habitat variables for the reasons discussed in the brood-rearing section of the breeding season model. Although acorns and other mast are an important winter food source, wood ducks will use other foods if necessary. It is assumed that food suitability will vary directly with cover suitability, and is not considered as a separate winter life requisite in this model.

Model Relationships - Breeding and Winter

Suitability Index (SI) graphs for habitat variables. This section contains suitability index graphs that illustrate the habitat relationships described earlier. Suitability index graphs for both the breeding HSI model and the winter HSI model are presented in this section.

Cover type	Variable		
DF,DFW, DSW,HW,R	V_3	Density of potential nest sites/0.4 ha (1.0 acre). Determined by the equation: $(0.18 \times V_1) + (0.95 \times V_2)$ where V_1 = the number of potentially suitable tree cavities/0.4 ha, and V_2 = the number of nest boxes/0.4 ha (see Figure 4 for complete definition of V_1 and V_2).	
DFW,DSW, HW,R	V_4	Percent of the water surface covered by potential brood cover (see Figure 4 for definition).	

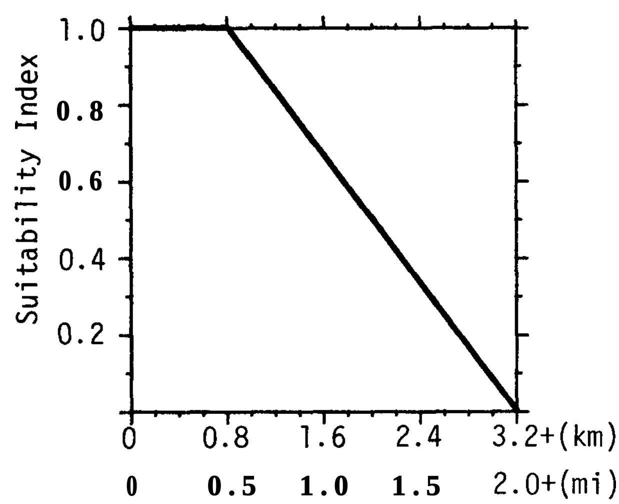
DFW,DSW, HW,R V_5 Percent of the water surface covered by potential winter cover (see Figure 4 for definition).



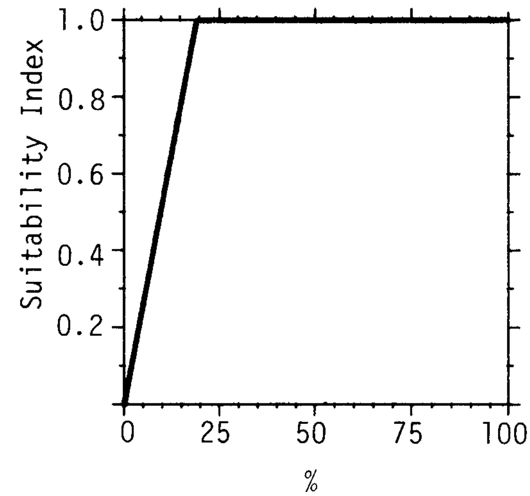
Suitability Index (SI) graphs for interspersion variables. This section contains suitability index graphs that illustrate the relationship between interspersion variables and breeding habitat suitability for the wood duck. The use of these graphs is explained under HSI determination.

Variable

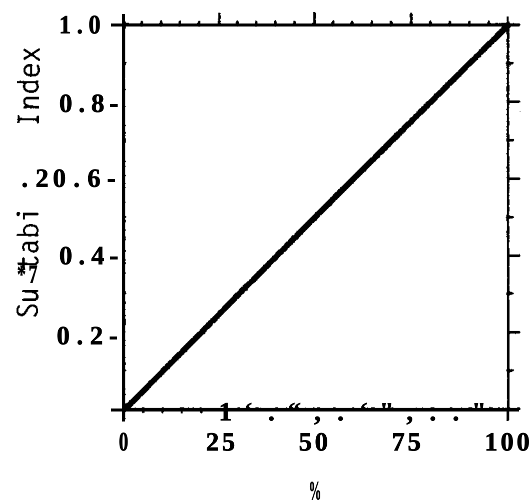
V_6 Distance between cover types.



V_7 Percent of area providing equivalent optimum nesting habitat.



V_8 Percent of area providing equivalent optimum brood-rearing habitat.



Determination of life requisite values. The determination of life requisite suitability indices by cover type with this model involves simple one-variable equations. The nesting value in all cover types equals the SI of V_3. Brood habitat suitability and winter habitat suitability in all cover types except deciduous forest, equals the SI of V_4 and V_5, respectively.

HSI determination - breeding HSI model. It is possible that some cover types will provide nesting habitat but not brood-rearing habitat, or brood habitat but not nesting habitat. In order to adequately evaluate breeding habitat, juxtaposition and composition of resources must be considered. Several steps and calculations are necessary in order to properly incorporate interspersion variables into the HSI determination. They are as follows:

1. Compute the nesting and brood-rearing values for each cover type by collecting field data for each habitat variable, entering this data into the proper suitability index curve, and using the resulting index values in the appropriate life requisite equations. If either nesting or brood-rearing equals zero in all cover types, then the HSI will equal zero and no further calculations are necessary.

2. Determine the relative area (%) of each cover type within the study area as follows:

$$\text{Relative Area (\%) for Cover Type A} = \frac{\text{Area of Cover Type A}}{\text{Total Area of All Cover Types used by the Wood Duck}} \times 100$$

Consider only those cover types used by the wood duck in determining this percentage.

3. Determine which cover types are not providing either nesting or brood-rearing habitat. For each of these cover types, a suitability index for juxtaposition of resources must be computed using V,.

This is accomplished by selecting random points on a map in each cover type missing a life requisite and measuring the distance to the edge of the nearest other cover type that provides that life requisite. Enter each distance measurement into the SI graph for V_6, record the individual interspersion indices, and calculate the average interspersion index for each cover type. If both nesting and brood-rearing habitat are provided within a specific cover type, the interspersion index equals 1.0 for the cover type.

4. Modify the relative area (%) of each cover type missing a life requ site by multiplying the relative area by the average interspersion index for that cover type. This determines the useable relative area (%) of each cover type. For those cover types that provide all life requisites the useable relative0 area (%) is the same as the relative area (%).

5. To determine the % area in optimum condition for any life requisite, first multiply the useable area (%) for each cover type by the life requisite values for that cover type (from 1 above). Sum the products of this multiplication across all cover types for each life requisite. The sum for each life requisite is the equivalent percent area that provides that life requisite at optimal levels (this is actually an equivalent figure, i.e., 100% of the area at a 0.5 value is equal to 50% of the area at an optimal, 1.0 value).

6. To determine overall life requisite values enter the value determined in Step 5 for nesting into the SI graph for V_7, and the value

determined for brood-rearing into the SI graph for V,. The resulting index value from V_7 is the overall nesting value, and the index value from V_8 is the overall brood-rearing value.

7. The HSI is equal to the lowest of the overall life requisite values. This single HSI value is considered to represent breeding suitability across the entire area evaluated.

HSI determination - winter HSI model. The winter HSI for the wood duck in a specified cover type equals the winter cover value (i.e., the SI for V,) determined for that cover type.

HSI determination for year-round use areas. The HSI models presented here are designed to evaluate breeding and winter habitat separately. In those areas where the wood duck is a resident species, it may be desirable to assign one overall HSI to a study area. In order to do so, a weighted (by cover type area) average HSI for winter habitat is determined and compared to the single HSI determined for breeding habitat. Because wood ducks may move between winter habitat and breeding habitat, the HSI in areas of permanent residency should equal the highest of the values determined for breeding and winter habitat suitability.

Application of the Models

Model limitations. These models represent a relatively simple approach to evaluating wood duck habitat suitability during the breeding season and winter. The use of cover estimates as surrogate measures of food suitability is perhaps the most important limitation of this model. Other factors that affect food suitability, such as wetland dynamics, and more direct food measurements are not included in this model because of the lack of adequate literature in these areas. Fredrickson (pers. comm.) indicates that current studies have the potential to address the unknowns in these models and that it should be possible to improve these models in the next few years. However, until such information becomes available, users should be aware of the model's limitations, especially in regards to wetland dynamics. For example, flooded lowland forests potentially provide an abundant source of macroinvertebrates to hens prior to nesting, also to broods during the first few weeks after hatching, and to wintering wood ducks. The quality of this habitat may be high even in the absence of optimum cover conditions as depicted by Variables 4 and 5 in this model. However, means to accurately and directly address the impacts of wetland dynamics on a macroinvertebrate food base are not currently available. The major problem limiting the use of the winter HSI model is that the model does not include an assessment of the importance of wetland complexes to wintering wood ducks (Fredrickson, pers. comm.). Rather, each wetland type is evaluated individually, since the means of evaluating a large variety of arrangements of wetlands is not currently available. Users of this model should use the Habitat Use Information section of this model, as well as local information, to adapt this model to local conditions, if necessary.

Use of model variables. Although these models provide a relatively simple means of evaluating the suitability of wood duck habitat, use of the breeding HSI model requires an estimate of the number of potential nest cavities in trees. Sampling of cavities in live trees is difficult and likely to provide an underestimate. Several options, other than intensive sampling, are available for estimating density of potential nest sites. In areas that are managed for wood ducks with a nest box program, optimum conditions may be provided by artificial sites alone. In cases where there are at least 5.3 nest boxes/0.4 ha (1.0 acre), optimum suitability levels have been reached, and a survey of potential natural nest sites is unnecessary. Alternatively, the potential for cavity production in various cover types can be estimated based on species composition and size classes of trees. McGilvrey (1968) provides a list of desirable tree species for cavity production by geographic region. The minimum dbh of a potential nest tree is 35 cm (14 inches), although the most suitable cavity trees range from 60 to 90 cm (24 to 30 inches) dbh. Intensive sampling of a limited area may provide an adequate estimate of cavity density, or an estimate may be interpolated from available literature (e.g., Dreis and Hendrickson 1952; Bellrose et al. 1964; Weier 1966; Gilmer et al. 1978) or provided by local knowledge.

Definitions of habitat variables and suggested field measurement techniques (Hays et al. 1981) are provided in Figure 4.

SOURCES OF OTHER MODELS

Several other attempts have been made to develop habitat models for the wood duck, including models developed for use with the Habitat Evaluation Procedures in Missouri (Flood et al. 1977; Hallett and Fredrickson 1980; Urich et al. 1983). The Missouri models provide a means of ranking habitat suitability based on habitat characteristics. Flood et al. (1977) includes the wood duck and hooded merganser (Lophodytes cucullatus) in a model for waterfowl in bottomland hardwood, upland hardwood, and riverine cover types. The model in Hallett and Fredrickson (1980) is intended for use in both bottomland and upland hardwood cover types and is a refinement of the model in Flood et al. (1977). The model in Urich et al. (1983) is intended for use in bottomland hardwoods and is a modification of the two previous Missouri models. The Missouri models evaluate habitat suitability only in bottomland and/or upland hardwood forests, and do not provide criteria for evaluating the suitability of other wetland types for wood ducks. They are most useful, therefore, where wood duck habitat is provided by upland hardwood forests and forested wetlands. A major difference between the Missouri models and the breeding season HSI model presented here is the method by which interspersion variables are treated. The Missouri models consider the distance between the cover type being evaluated and some critical resource (i.e., timbered habitat or permanent water) as a habitat variable. In our model, we use the distance between a cover type and a missing life requisite (i.e., nesting or brood-rearing habitat) to modify the available habitat area and also use life requisite composition suitability index curves to evaluate the balance of life requisites provided by a given area. A final major difference between the Missouri models and the breeding season HSI model presented here lies in the manner in

Variable (definition)		Cover types	Suggested technique
V_1	Number of potentially suitable tree cavities/ 0.4 ha (1.0 acre) [tree cavities/0.4 ha (1.0 acre) with minimum entrance dimensions of 7.6 by 10.0 cm (3.0 by 4.0 inches); cavities may be in live trees or snags].	DF,DFW,DSW, HW,R	Quadrat
V_2	Number of nest boxes/ 0.4 ha (1.0 acre) (the number of artificial wood duck nest sites/0.4 ha that are predator-proof and maintained).	DF,DFW,DSW, HW,R	Quadrat
V_3	Density of potential nest sites/0.4 ha (1.0 acre) (an estimate of the density of natural and artificial nest sites available to wood ducks. Determined by the following equation: $(0.18 \times V_1) + (0.95 \times V_2)$ where V_1 and V_2 are as defined above).	DF,DFW,DSW, HW,R	----
V_4	Percent of the water surface covered by potential brood cover [an estimate of the proportion of a wetland's water surface area that is covered by shrub cover, overhanging tree crowns within 1 m (3.3 ft) of the water surface, woody downfall, and herbaceous vegetation].	DFW,DSW, HW,R	Remote sensing, ocular estimation, line intercept

Figure 4. Definitions of variables and suggested measurement techniques.

Variable (definition)		Cover types	Suggested technique
V_5	Percent of the water surface covered by potential winter cover (same as for V_4 except that only winter persistent species should be considered in the herbaceous vegetation component).	DFW,DSW HW,R	Remote sensing, ocular estimation, line intercept

Figure 4. (concluded).

which HSI values are determined. The former models result in one HSI value for each cover type, while this model results in one HSI value for the aggregation of cover types used by the wood duck in a given area.

A simple approach to evaluating wood duck breeding habitat along streams was developed by Burbank (1972). This approach is based on tree size and subjective evaluation of general stand conditions. McGilvrey (1968) provides criteria that can be used to develop a habitat model for the wood duck for several geographic areas.

REFERENCES

Alexander, H. L., Jr. 1977. Mallard and wood duck brood survival at Remington Farms, Chestertown, Maryland. Trans. Northeast Fish Wildl. Conf. 34:221-230.

Baines, A. S. 1971. Estimates of the population numbers of juvenile wood ducks (Aix sponsa) on two brood rearing areas. M.S. Thesis, N.C. State Univ., Raleigh. 56 pp.

Ball, I. J., Jr. 1973. Ecology of duck broods in a forested region of north-central Minnesota. Ph.D. Thesis, Univ. Minnesota, St. Paul. 67 pp. Cited by Gilmer et al. 1978.

Beard, E. G. 1964. Duck brood behavior at the Seney National Wildlife Refuge. J. Wildl. Manage. 28(3):492-521.

Bellrose, F. C. 1976. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, PA. 544 pp.

_______________. Personal communication (phone conversation record 17 February 1983). Illinois Natural History Survey, Box 599, Havana, IL 62644.

Bellrose, F. C., K. L. Johnson, and T. U. Meyers. 1964. Relative value of natural cavities and nesting houses for wood ducks. J. Wildl. Manage. 28(4):661-676.

Burbank, J. H. 1972. A quick method to assess streamside wood duck breeding habitat. Proc. Southeastern Assoc. Game and Fish Commissioners 26:205-206.

Brakhage, G. K. 1966. Management of mast crops for wood ducks. Pages 75-80 in J. B. Trefethen, ed. Wood duck management and research: a symposium. Wildl. Manage. Inst., Washington, DC.

Brown, B. W. 1973. The Big Lake wood duck: a two-year study of its pre-flight mortality, nest population, growth and migration, 1970-1971. Proc. Southeastern Assoc. Game and Fish Commissioners 26:195-291. Cited by Bellrose 1976.

Clawson, R. L., G. W. Hartman, and L. H. Fredrickson. 1979. Dump nesting in a Missouri wood duck population. J. Wildl. Manage. 43(2):347-353.

Coulter, M. W. 1957. Food of wood ducks in Maine. J. Wildl. Manage. 21(2):235-236.

Dreis, R. E., and G. O. Hendrickson. 1952. Wood duck production from nest boxes and natural cavities on the Lake Odessa area, Iowa, in 1951. Iowa Bird Life 22(2):18-22. Cited by Grice and Rogers 1965.

Drobney, R. D. 1980. Reproductive bioenergetics of wood ducks. Auk 97(3):480-490.

Drobney, R. D., and L. H. Fredrickson. 1979. Food selection by wood ducks in relation to breeding status. J. Wildl. Manage. 43(1):109-120.

Flood, B. S., M. E. Sangster, R. D. Sparrowe, and T. S. Baskett. 1977. A handbook for habitat evaluation procedures. U.S. Dept. Int., Fish Wild. Serv. Resour. Publ. 132. 77 pp.

Fredrickson, L. H. Personal communication (letters dated 24 February 1983 and 11 April 1983). Director, Gaylord Memorial Laboratory, Univ. of Missouri, Puxico, MO 63960.

Gilmer, D. S., I. J. Ball, L. M. Cowardin, J. E. Mathisen, and J. H. Riechmann. 1978. Natural cavities used by wood ducks in north-central Minnesota. J. Wildl. Manage. 42(2):288-298.

Grice, D., and J. P. Rogers. 1965. The wood duck in Massachusetts. Final Rep. Fed. Aid Proj. W-19-R, Mass. Div. Fish Game. 96 pp.

Hallett, D. L., and L. H. Fredrickson. 1980. Wood duck (Aix sponsa). Pages 106-114 in T. S. Baskett, D. A. Darrow, D. L. Hallett, M. J. Armbruster, J. A. Ellis, B. F. Sparrowe, and P. A. Korte (eds.). A handbook for terrestrial habitat evaluation in central Missouri. U.S. Dept. Int., Fish Wildl. Serv. Resour. Publ. 133. 155 pp.

Hansen, H. L. 1966. Silvical characteristics of tree species and decay process as related to cavity production. Pages 65-69 in J. B. Trefethen, ed. Wood duck management and research: a symposium. Wildl. Manage. Inst., Washington, DC.

Hardister, J. P., Jr., F. E. Hester, and T. L. Quay. 1962. Movements of juvenile wood ducks as measured by web-tagging. Proc. Southeastern Assoc. Game and Fish Commissioners 16:70-75.

Hays, R. L., C. Summers, and W. Seitz. 1981. Estimating wildlife habitat variables. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-81/47. 111 pp.

Hepp, G. R., and J. D. Hair. 1977. Wood duck brood mobility and utilization of beaver pond habitats. Proc. Southeastern Assoc. Game and Fish Commissioners 31:216-225.

Heusmann, H. W., R. Bellville, and R. G. Burrell. 1980. Further observations on dump nesting by wood ducks. J. Wildl. Manage. 44(4):908-915.

Hocutt, G. E., and R. W. Dimmick. 1971. Summer food habits of juvenile wood ducks in east Tennessee. J. Wildl. Manage. 35(2):286-292.

Jones, R. E., and A. S. Leopold. 1967. Nesting interference in a dense population of wood ducks. J. Wildl. Manage. 31(2):221-228.

Landers, J. L., T. T. Findley, and A. S. Johnson. 1977. Feeding ecology of wood ducks in South Carolina. J. Wildl. Manage. 41(1):118-127.

Leopold, F. 1966. Experiences with home-grown wood ducks. Pages 113-123 in J. B. Trefethen, ed. Wood duck management and research: a symposium, Wildl. Manage. Inst., Washington, DC. Cited by Bellrose 1976.

McGilvrey, F. B. 1966. Fall food habits of wood ducks from Lake Marion, South Carolina. J. Wildl. Manage. 30(1):193-195.

McGilvrey, F. B. (compiler). 1968. A guide to wood duck production habitat requirements. Bur. of Sport Fish. and Wildl., Resour. Publ. 60. 32 pp.

McGilvrey, F. B. 1969. Survival in wood duck broods. J. Wildl. Manage. 33(1):73-76.

Morse, T. E., and H. M. Wight. 1969. Dump nesting and its effect on production in wood ducks. J. Wildl. Manage. 33(2):284-293.

Palmer, R. S. (ed.). 1976. Handbook of North American birds: Volume 3. Yale Univ. Press, New Haven and London. pp. 252-277.

Parr, D. E., M. D. Scott, and D. D. Kennedy. 1979. Autumn movements and habitat use by wood ducks in southern Illinois. J. Wildl. Manage. 43(1):102-108.

Prince, H. H. 1965. The breeding ecology of wood duck (*Aix sponsa* L.) and common goldeneye (*Bucephala clangula* L.) in central New Brunswick. M.S. Thesis, Univ. New Brunswick, Fredericton. 109 pp. Cited by Bellrose 1976.

Ridlehuber, K. T. 1980. Wood duck production and habitat use. Ph.D. Diss., Texas A&M Univ., College Station. 52 pp. (Abstract only, from Diss. Abstr. Int. B Sci. Eng. 41(6):1998.)

Strader, R. W., R. E. Murry, Sr., H. R. Perry, Jr., and R. B. Hamilton. 1978. Hen wood duck calls brood from neighboring nest box. J. Wildl. Manage. 42(4):919-920.

Strange, T. H., E. R. Cunningham, and J. W. Goertz. 1971. Use of nest boxes by wood ducks in Mississippi. J. Wildl. Manage. 35(4):786-793.

Urich, D. L., J. P. Graham, and C. C. Cook (compilers). 1983. A handbook for habitat-evaluation in Missouri. Missouri Dept. Conserv., U.S. Soil Conserv. Serv. (Columbia), and U.S. Fish Wildl. Serv. (Columbia). 148 pp.

U.S. Fish and Wildlife Service. 1981. Standards for the development of Habitat Suitability Index models. 103 ESM. U.S. Dept. Int., Fish Wildl. Serv., Div. Ecol. Serv. n.p.

U.S. Forest Service. 1971. Wildlife habitat management handbook. Southern Region. U.S. Dept. Agric., For. Serv. FSH 2609.23 R. n.p.

Vance, J. F., Jr. 1968. A characterization of a brood-rearing area of the wood duck (Aix sponsa Linneaus). M.S. Thesis, N.C. State Univ., Raleigh. 51 pp.

Webster, C. G., and F. B. McGilvrey. 1966. Providing brood habitat for wood ducks. Pages 70-75 in J. B. Trefethen, ed. Wood duck management and research: a symposium. Wildl. Manage. Inst., Washington, DC.

Weier, R. W. 1966. A survey of wood duck nest sites on Mingo National Wildlife Refuge in southeast Missouri. Pages 91-108 in J. B. Trefethen, ed. Wood duck management and research: a symposium. Wildl. Manage. Inst., Washington, DC.

Wenner, K. C., and W. R. Marion. 1981. Wood duck production on a northern Florida phosphate mine. J. Wildl. Manage. 45(4):1037-1042.

0272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. FWS/OBS-82/10.43	2.	3. Recipient's Accession No.

4. Title and Subtitle Habitat Suitability Index Models: Wood duck	5. Report Date July 1983 6.
7. Author(s) Patrick J. Sousa and Adrian H. Farmer	8. Performing Organization Rept. No.
9. Performing Organization Name and Address Habitat Evaluation Procedures Group U.S. Fish and Wildlife Service Western Energy and Land Use Team Creekside One Building 2627 Redwing Road Fort Collins, CO 80526-2899	10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address Western Energy and Land Use Team Division of Biological Services Research and Development Fish and Wildlife Service U.S. Department of the Interior Washington, DC 20240	13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop models for breeding and wintering habitats for the wood duck (*Aix sponsa*). The models are scaled to produce indices of habitat suitability between 0 (unsuitable habitat) and 1 (optimally suitable habitat). Habitat suitability indices are designed for use with Habitat Evaluation Procedures previously developed by the U.S. Fish and Wildlife Service.

17. Document Analysis a. Descriptors

Mathematical models
Birds
Wildlife
Habitability

b. Identifiers/Open-Ended Terms

Wood duck
Aix sponsa
Habitat Suitability Index

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release unlimited	Unclassified	77
	20. Security Class (This Page)	22. Price
	Unclassified	

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

☆ U.S. Government Printing Office 1984 - 681-459/515 Reg. 8

DEPARTMENT OF THE INTERIOR
U.S. FISH AND **WILDLIFE** SERVICE

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving thsenvironmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

Great Trinity Forest Management Plan

Wildlife Management

White-tailed Deer

(Odocoileus virginianus)

White-tailed Deer

Order Artiodactyla : Family Cervidae : *Odocoileus virginianus* (Boddaert)

Description. A relatively small deer with relatively short ears; all major points of the antlers come off the main beam; tail relatively long, broad basally, and white underneath; metatarsal gland small and circular; females usually antlerless; upperparts reddish brown in summer, bright grayish fawn sprinkled with black in winter; face and tail usually lack blackish markings; underparts white. Dental formula as in the mule deer. External measurements average: (males) total length, 1,800 mm; tail, 300 mm; hind foot, 450 mm; females slightly smaller. Weight of males, 30-70 kg.

Distribution in Texas. Suitable brushy or wooded country throughout the state.

Habits. White-tailed deer occur almost entirely in the hardwood areas within their general range except for the southeastern section of Texas where the principal vegetation is a mixture of pines and hardwoods or nearly pure stands of pines. In the Chisos Mountains of Texas they occur in the mountains, whereas the mule deer occupies the lower foothills and broken deserts; in most other places this habitat relationship is reversed. For example, in the Guadalupe Mountains the whitetail occurs almost entirely in the foothills; the mule deer, in the higher mountains.

White-tailed deer have a relatively small home range and cruising radius. Normally, when food conditions are adequate, the deer tend to stay in one locality for long periods. For example, in the Edwards Plateau region, where deer were belled in an experimental study, many of the marked deer remained on an area of 259 ha for at least 3 years. A few of them were found as far away as 8 km.

Deer are most active just before sunset and again shortly after sunrise. It has been found in experimental trials that they are most easily observed in the hour just before dark. During the middle part of the day they are generally bedded down in some thicket or on some promontory where they are more or less protected. Under cover of darkness it is not uncommon for them to feed well into the night, but there is usually a period of resting and cud chewing during the middle part of the night. In regions heavily populated with deer their trails and beds, the latter usually scraped out places under the protection of overhanging boughs or at the bases of trees, are readily seen and give some clue to the density of the population.

As with most other mammals, the feeding habits of whitetails vary from place to place and from season to season. E. L. Atwood listed more than 500 different plants utilized by whitetails in the United States. Availability determines in large measure what the animals will eat but if adequate food is available, the deer are dainty eaters and exercise considerable choice in the items taken. In the Chisos Mountains of Trans-Pecos Texas, whitetails feed extensively on mountain mahogany and other low shrubs. In the Edwards Plateau region the deer graze twice as much as they browse. There, 67% of their total feeding time was spent in grazing on forbs and grasses, 26% in eating fruits and mast, and only 7% in browsing. In South Texas, however, browse species make up the bulk of the diet.

The 10 most favored foods as observed in the Edwards Plateau of Texas are grasses and weeds, Mexican persimmon, live oak acorns, live oak leaves, mesquite beans, oats or other grain, Spanish oak acorns, spike rush, *Foresteria* or elbow bush, and turkey pear. On the basis of food consumed, seven deer will eat about as much as one medium-sized cow.

White-tailed deer are polygamous. The rut begins in early fall and continues through early winter. The onset of breeding varies considerably from one section of the country to another. In coastal Texas, for example, it is not uncommon for breeding to begin as early as September. In the Edwards Plateau, not more than 300 km distant, the peak of the breeding season is in November, whereas in the southern "brush country" section of Texas the peak is in late November and December.

The fawns, usually one or two in number, are dropped after a gestation period of approximately 7 months and hidden by the female for 10 days to 2 weeks. She goes several times daily to nurse them but as soon as they are strong enough to follow her about they do so. The spots are retained until the fawns molt in early fall by which time they are usually weaned. Normally, sexual maturity is not reached in females until the second year but occasionally, when food conditions are excellent, female fawns mate the first fall and produce offspring the following spring when they themselves are only 1 year old. This appears to be unusual throughout most of their range, however.

There is a relationship between testicular activity and the growth and shedding of antlers. The antlers begin their annual growth when the testes and accessory organs are inactive, harden and lose their velvet when these glands are enlarging, and are shed when they begin to decline. Castration following loss of the velvet results in shedding within 30 days. New growth, which occurs at the normal time, is abnormal in shape and the velvet is not lost. Growth ceases at the usual time and part of the growth, being somewhat fragile, may be lost by accident. Renewed growth activity follows in the spring. Eventually, an aggravated burr is produced. These events have been interpreted as indicating that antler growth is under the influence of a nontesticular hormone, possibly from the anterior pituitary, and antler hardening and subsequent loss of the antler is due to the action of a testicular hormone.

One can estimate the age of whitetails by examination of the teeth. At 9 months of age the fawn will be acquiring the middle pair of permanent incisors while the remainder of the incisors as well as the premolars will be milk teeth. At this age one molar on either side of each jaw is well developed while the second is barely breaking through the gum. At the age of 1½ years all milk incisors have been replaced by permanent teeth. At least two molars are fully developed while the third may be in any condition from barely emerging from the mandible to fully emerged. At the age of 2 years the full set of permanent teeth is acquired. Beyond 2 years age determination is somewhat uncertain but can be roughly estimated by the wearing of the teeth. Wear of the teeth is gradual until at 5 years the ridges of enamel are no longer sharp, but rise slightly and gradually above the dentine. At still later ages the crowns of the premolars and molars rise only a short distance above the gums, and the grinding surfaces are worn practically smooth.

Contrary to popular opinion, it is almost impossible to determine accurately the age of deer by the number of points on the antlers. For example, the shed antlers collected from one buck in Texas over a period of 5 years had each year either four or five points on each side. There is some correlation between age and diameter of the beam of the antler, however. The older bucks tend to have heavier antlers, but antler development is also so closely associated with nutrition that it is hazardous to make generalizations concerning age and diameter of the beam. Also, a certain amount of geographic variation is seen in antler development.

White-tailed deer are the most important big game animals in Texas. In the face of an expanding human population this species has done remarkably well. It is estimated that our 1991 white-tailed deer population numbered more than 3.1 million in spite of heavy hunting pressure and approximately 474,000 were harvested by hunters in that year.

On some ranges there is considerable competition for forage between white-tailed deer and domestic livestock. This is particularly true between deer and domestic goats. Competition between deer and cattle is not so severe. Where abundant in farming areas, deer often become pests and destroy such crops as peas, peanuts, wheat, oats, and other small grains.

<u>Great Trinity Forest Management Plan</u>

Wildlife Management

Learn About Whitetails

Learn About Whitetails

by Robert L. Cook
Updated and revised 1992
From Texas Parks and Wildlife Magazine, October 1975
* Reproduced from PWD-LF-W7000-0007-2/93.

Exploration and settlement of the American frontier would have been extremely difficult without the white-tailed deer. Early colonists and explorers utilized the meat and skins of these animals extensively, and deer hides later served as a medium of exchange between trappers, frontier scouts, Indians and traders.

Deer were even more important to the American Indians prior to settlement of the nation, providing clothing and food. Deer were also an important factor in the folklore and religion of native tribesmen.

Indiscriminate slaughter by commercial meat and hide hunters and ignorance of the deer's habitat requirements almost caused its extermination near the end of the 19th century. It was reported, for example, that an early Texas trader operating in Indian country at Trading House Creek (near present site of Waco) shipped approximately 75,000 deer skins from 1844 through 1853.

Public concern for survival of the species brought about a series of protective measures by the Texas Legislature near the turn of the century. A five-month closed season during which deer could not be hunted was enacted in 1881. The bag limit was established at six bucks per season in 1903 and was reduced to three bucks per season in 1907.

The first hunting licenses were sold in Texas in 1909. In 1919, six game wardens were hired to patrol the entire state.

Additional interest and protection by landowners, sportsmen and law enforcement personnel helped deer populations increase steadily during the 1930s and 1940s. Statewide trapping and restocking programs established deer herds in previously uninhibited areas. Sales of hunting licenses increased dramatically – 382,249 in 1955, 571,058 in 1964 and over one million in 1972.

The white-tailed deer is now the most numerous big game animal in Texas and in the United States. Aesthetically and emotionally, the whitetail holds a place of distinction in the hearts and minds of many Texans.

Research and management projects concerning the whitetail and its habitat requirements are conducted by wildlife biologists of the Texas Parks and Wildlife Department, federal agencies, many universities and several private research establishments in Texas.

Research activities by the wildlife biologists of the Texas Parks and Wildlife Department are 75 percent funded from federal excise taxes on firearms and ammunition. Deer are of primary importance on several of the wildlife management areas and public lands operated by this department. Research activities also are conducted on National Wildlife Refuges, National Forests and Department of Defense lands. The Texas Parks and Wildlife Department game warden field force now numbers some 460 officers. These highly skilled and trained officers provide law enforcement services essential to continued survival of the whitetail.

The whitetail is one of the most researched, observed, sought after, cussed and discussed of all wildlife species in Texas. Few of us, however, are aware of the basic principles which rule this majestic animal's life. Following are some of the most frequently asked questions about white-tailed deer in Texas.

How many kinds of deer are there in Texas?

The Texas white-tailed deer, *Odocoileus virginianus texana*, occurs almost statewide. There were several subspecies of whitetail in the state years ago. However, due to expanding-overlapping ranges and restocking efforts in recent times, the subtle differences between subspecies have been lost except for the isolated population of Carmen Mountain white-tailed deer, *Ododoileus virginianus carminus*, in the Big Bend National Park area. Although found almost statewide in brushy or wooded areas, the heaviest deer populations are located in the central one-third of the state. The mule deer, *Odocoileus hemionus*, is a different species which occurs primarily west of the Pecos River and in parts of the High Plains of the Texas Panhandle.

How many deer are there in Texas?

Texas has more white-tailed deer than any other state. Population estimates in recent year range from three to four million. Population estimates vary from year to year, depending upon reproduction, survival and losses due to malnutrition and disease.

How many white-tailed deer are legally harvested by sportsmen in Texas each year?

It varies of course, however, an estimated 430,000-500,000 whitetails are harvested by sportsmen in Texas annually – more than any other state.

Isn't that too many?

No. Current harvest rates account for only about 15 percent of the herd annually. Research indicates that about 20 percent of most populations should be removed annually by sportsmen. Biologically sound harvest rates and habitat management programs are necessary in Texas to prevent waste due to overpopulation, to achieve maximum utilization of this valuable natural resource and to insure the whitetail's continued survival. For example, since the initiation of the program in 1953, more than two million antlerless or doe deer have been harvested from the established deer herds in the state. White-tailed deer in Texas must be harvested to protect the habitat which will not only support the deer and other game species but also is critical to many non-game and threatened species.

How are deer counted?

Several methods of estimating deer numbers are used in Texas:

1. The walking deer cruise line. During the fall months, wildlife biologists walk census lines which have been placed in representative deer habitat and count the deer observed. This method is used extensively in Texas, and there are several hundred such deer census lines in the state.

2. Counts from fixed-winged aircraft. This method is used in areas of the South Texas brush country. Observers count deer seen on strips of deer habitat of known width and length.
3. Track count method. Counting deer tracks on selected sites during late summer is a method frequently used in heavily wooded areas of East Texas.
4. Spotlight counts. Counting deer at night with the use of spotlights along pasture roads or lightly traveled public roads is a method biologists have recently put into use. It is an excellent census method in areas with low deer populations.

Caution: Biologists always notify all landowners along their spotlight census routes. They drive vehicles clearly marked "Texas Parks and Wildlife Department" and "Deer Census". Any other spotlighters should be reported to the local game warden.

5. Several other deer census methods are used by Parks and Wildlife Department personnel. Counts from helicopters and late evening counts from vehicles are good deer census techniques.

It is important to understand that these "counts" or "censuses" are population trend indicators, no one knows exactly how many deer are present in Texas.

<u>What do deer eat?</u>

Deer eat mostly browse (leaves, twigs, young shoots of woody plants and vines) and forbs (weeds and other broad-leafed flowering plants). They eat some grass, but only when it is green and succulent. Sheep, goats and foreign big game species compete directly with the whitetail for preferred deer foods. Deer food shortages usually occur during late summer and winter months. Adequate forage is usually available during spring and fall seasons. A variety of foods and habitat types is essential to good deer production and survival.

The following plants are examples of some good native deer foods in Texas which are readily taken by deer when and where they are available.

Browse: oak leaves and acorns, yaupon, greenbriar, prickly pear and fruit, hackberry, mulberry, rattan, or supplejack, sumac, mesquite beans and dried leaves, hawthorns, poison oak, American beautyberry, wild cherry and plum, wild grape, honeysuckle, dogwood, elm, blackberry and dewberry, gum elastic (chittum), acacias (catclaw), ephedra, walnut, guayacan, wild chinaberry, kidneywood, Brasil and other condalias.

Grasses: rescue grass, Texas wintergrass, Ozarkgrass, fall witchgrass, panic grasses, sedges, and rushes.

Forbs: bundle flower, euphorbia(s), whorled nodviolet, bayflower, oxalis, wooleywhite, tickclovers, filaree, clover, verbena, arrowleaf sida, wild lettuce, wild onions, old man's beard, wildbean, snoutbean, lespedezas, spiderwort, vetches (milkvetch, etc.), lamb's quarters, plantain, groundcherry, pigweed or carelessweed and partridge peas.

How long do deer live?

Deer in controlled situations have been known to live 15 to 20 years. It is unusual, however, for a deer in the wild to live more than 10 years, because its teeth usually wear out during the eighth or ninth year.

How can the age of a deer be determined? Is the number of antler points one method?

Deer age is determined by tooth replacement and tooth wear of the premolars and molars (back teeth) of the lower jaw. Unlike sheep, deer cannot be aged by their front teeth, and age cannot be determined by antler characteristics.

Does a buck deer keep the same set of antlers each year?

No. A buck grows a new set of antlers (not horns) each summer. The size of the antlers depends primarily upon the quality and quantity of food the buck eats and his age. The more nutritious the food and the more there is of it during the antler-growing season, the better his antlers will be. With favorable conditions, antler size and spread will increase with deer age. After the sixth year, however, antlers usually decline in size due to the deer's inability to properly chew and digest food.

What happens to the antlers each year?

Buck deer shed their antlers following the mating season each year. Antler shedding is triggered by the cessation of production of a hormone which also terminates the breeding season. Most bucks in Texas shed their antlers during late January and February. Shed antlers quickly deteriorate or are eaten by rodents and other animals for their calcium content. New antlers start growing and become noticeable "in velvet" during May and June. Good nutrition during this period is critical for good antler growth.

Shouldn't spike bucks be protected since they are young and will be the breeding bucks of the future?

The harvest of spike-antlered bucks is another important aspect of a management program. Spike-antlered bucks are the result of inadequate nutrition, age and genetics, or combination of these factors. Spikes are generally found in combination of these factors. Spikes are generally found in the yearling of 1-½ year old age class; however, yearling bucks can produce 4 to 8 points if nutrition is adequate. For nutrition to be adequate, deer numbers must be in balance with the habitat, competition with livestock must be minimal, and rainfall adequate. Additionally, research has shown that on the average, spike-antlered yearling bucks will remain inferior to fork-antlered yearling bucks when these two groups reach maturity. Consequently, spike-antlered bucks may be considered as part of the buck harvest quota. This permits the removal of poor quality bucks at an early age and it reduces hunting pressure on the more desirable bucks. The recommended spike buck harvest may comprise up to one-half of the buck harvest quota depending on how much the manager wants to reduce hunting pressure on better quality bucks and reduce numbers of spike bucks. An unlimited harvest of spike-antlered bucks is practical only under very intensive management. Importantly, the manager must remember that a high incidence of spike-antlered bucks is a symptom of rangeland overpopulated with deer and/or overstocked with domestic animals. These factors which limit deer quality must be corrected before the selective harvest of spike bucks is beneficial to the program.

When is the breeding season?

The breeding season for white-tailed deer in Texas ranges through the fall and winter months from about the first of September through mid-January. The peak breeding activity occurs in mid-November in Central Texas and late December in South Texas.

What is a good buck-doe ratio?

The buck-doe ratio in most of Texas is about one buck per three to five does (adult deer) which is satisfactory for good production and hunting. This ratio is not a major problem in Texas deer herd management at this time. An adequate harvest of antlerless deer would help maintain a good ratio of both sexes. It is recommended that game managers and landowners strive for a ratio of about 2.0 to 2.5 does per buck.

Won't the deer become smaller due to inbreeding if we don't bring some new blood lines?

No. The deer of Texas are direct descendants of isolated deer herds of many years ago. Inbreeding may occur in the wild, but it apparently is no problem. New blood lines are quickly absorbed into established genetic pools and no improvement in quality is noticed. Inferior quality or small deer result from poor range conditions or insufficient preferred forage and will not be improved by bringing in new bucks.

Does the Texas Parks and Wildlife Department restock deer?

Yes, but only in approved areas judged as potentially good deer habitat which presently have few or no deer. The deer trapping and restocking program was initiated in 1938 by the Game, Fish and Oyster Commission, predecessor of the Texas Parks and Wildlife Department. Since that time, more than 30,000 deer have been released in 160 Texas counties.

How many fawns will a doe have?

Normally, a doe deer in Texas will have her first fawn, which is usually a single, when she is two years old. Thereafter, if food conditions are adequate, the doe should normally have twin fawns almost every year until her sixth or seventh year, when the reproductive rate will begin to decline. Triplet fawns are uncommon, but do occur. Quadruplets have been reported.

The gestation period for deer is seven months.

According to reproductive studies, "old barren does," or does that have never produced fawns are uncommon and are no problem to deer herd management. The key to maximum production is an adequate supply of nutritious natural food.

Are more female fawns born than male fawns?

No. Male and female fawns are born in approximately equal numbers.

What are the most serious threats to deer herds in Texas?

1. Habitat destruction such as land clearing, root plowing, improved grass pastures, subdivisions, new lakes, expanding cities, etc.
2. Poor range or inadequate food supplies due to overgrazing by domestic livestock and overpopulations of deer, resulting in large-scale deer die-offs.

What are some of the most important limiting factors affecting white-tailed deer?

Rainfall is an important limiting factor. Extended periods of severe drought during the late summer and fall are especially harmful to fawns, yearlings and very old deer. Coyotes are a limiting factor in South Texas and in portions of Southeast-Central Texas. However, natural predators, such as coyotes, bobcats or eagles presently pose no serious threats to established deer herds of Texas. Efforts to control these predators are usually expensive and ineffective with regard to white-tailed deer. Good habitat and quality forage are the key to the survival of white-tailed deer in Texas.

What about hunting?

Legal hunting can be a limiting factor but is not currently a threat to deer populations. In fact, regulated hunting is the best way to crop the deer herd annually, much like a farmer-rancher would crop his herds of domestic livestock. Properly controlled and regulated, hunting is the most reasonable and humane method of maintaining and utilizing the extensive deer populations of Texas.

Will deer move great distances?

Not normally. A deer chased by dogs may run several miles, but will often circle and end up close to home. During the breeding season, some bucks will trail female deer out of their normal home range but will later return. Movement studies and radio-tracking research in Texas indicated that most deer spend their lives within about 1.5 miles of their birthplace.

What can I do to help the deer, increase deer numbers or improve the quality of deer?

1. Learn about the habitat requirements of deer. Become familiar with preferred deer foods in your area or the area where you vacation or hunt. Support practices which create good wildlife habitat and prevent destruction of existing habitat.
2. Landowners and operators should make every effort to provide adequate habitat and forage for deer and other wildlife. Competition by domestic sheep and goats should be reduced in some cases. Both sexes of deer should be reasonably, but adequately, harvested each year from well-established herds.
3. Sportsmen should obey state laws and those rules established by landowners. Sportsmen should not abuse the land on which they hunt, trespass where they do not have permission, take “sound shots” or misuse a firearm.
4. Everyone should cooperate with law enforcement officers responsible for protection of our wildlife. Violations should be reported immediately to the nearest game warden of the Parks and Wildlife Department, or to Operation Game Thief at 1-800-792-GAME.

5. Landowners and hunters can provide a significant service to the game management programs of Texas by completely and accurately providing harvest data. Whether it is solicited by mail questionnaire or in person by biologists in the field, at check stations or cold storage facilities, valid harvest information is vital to the formulation of effective hunting regulations. These regulations will allow the maximum harvest of surplus animals without endangering the broodstock necessary to replenish those populations.

Would it help to feed the deer some supplemental feed?

If deer take large quantities of supplemental feed (corn, etc.) there probably is a shortage of their natural preferred foods. The best solution to the problem is to improve availability of natural foods. Obviously, this cannot be achieved quickly and will result only from proper range management practices (grazing moderately, rotation grazing systems, etc.) If artificial feeding is necessary, deer should be supplied high-quality (14 to 16 percent protein) 3/16" pellets instead of corn, which is about eight percent protein. Marked improvement in body size and antler development should not be expected from artificial or supplemental feeding.

Researchers in Texas and other states have worked many years to obtain answers to some of the many questions concerning the white-tailed deer, its requirements and management. Continued research will reveal additional necessary information about this and other wildlife species. The well-being and continued survival of the whitetail in Texas, however, is dependent primarily upon the interest and concern of sportsmen, landowners and the conservation-minded public of our state.

How to Age Deer

Age of a deer is determined by tooth replacement and wear on molars and premolars of the lower jaw. As a deer grows older, certain portions of its teeth are worn enough to show definite differences from the teeth of other age classes.

A deer has only six jaw teeth, although they appear to have many more. The teeth are broken into two distinct categories: the premolars, which are numbered 1,2, and 3, and the molars, which are numbered 4, 5, and 6.

Deer are aged in fractions because they are born around July and are killed during the hunting season.

1 ½ year old: (long yearling): The long yearling deer is the most easily recognized of all age classes. The first three jaw teeth are milk teeth, which will be replaced around two years of age. These are worn smooth as a long yearling while the last three teeth remain sharp. The number 3 tooth has three cusps in the milk tooth stage, but only two cusps appear on the replaced tooth. Fawns in their first season will show little evidence of wear on their milk teeth.

2 ½ year old: The first three jaw teeth have been replaced by permanent teeth and all molars are sharp. The dentine of the first molar (tooth 4) is not as wide as the enamel which surrounds it.

3 ½ year old: The dentine in the first molar (tooth 4) is now as wide or wider than the enamel which surrounds it, and this is not true of the second molar or tooth 5.

4 ½ year old: The dentine of the first and second molars (teeth 4 and 5) is as wide or wider on both teeth, but not in tooth 6.

5 ½ year old: The dentine of all molars (teeth 4, 5, and 6) is now as wide or wider than the enamel surrounding it.

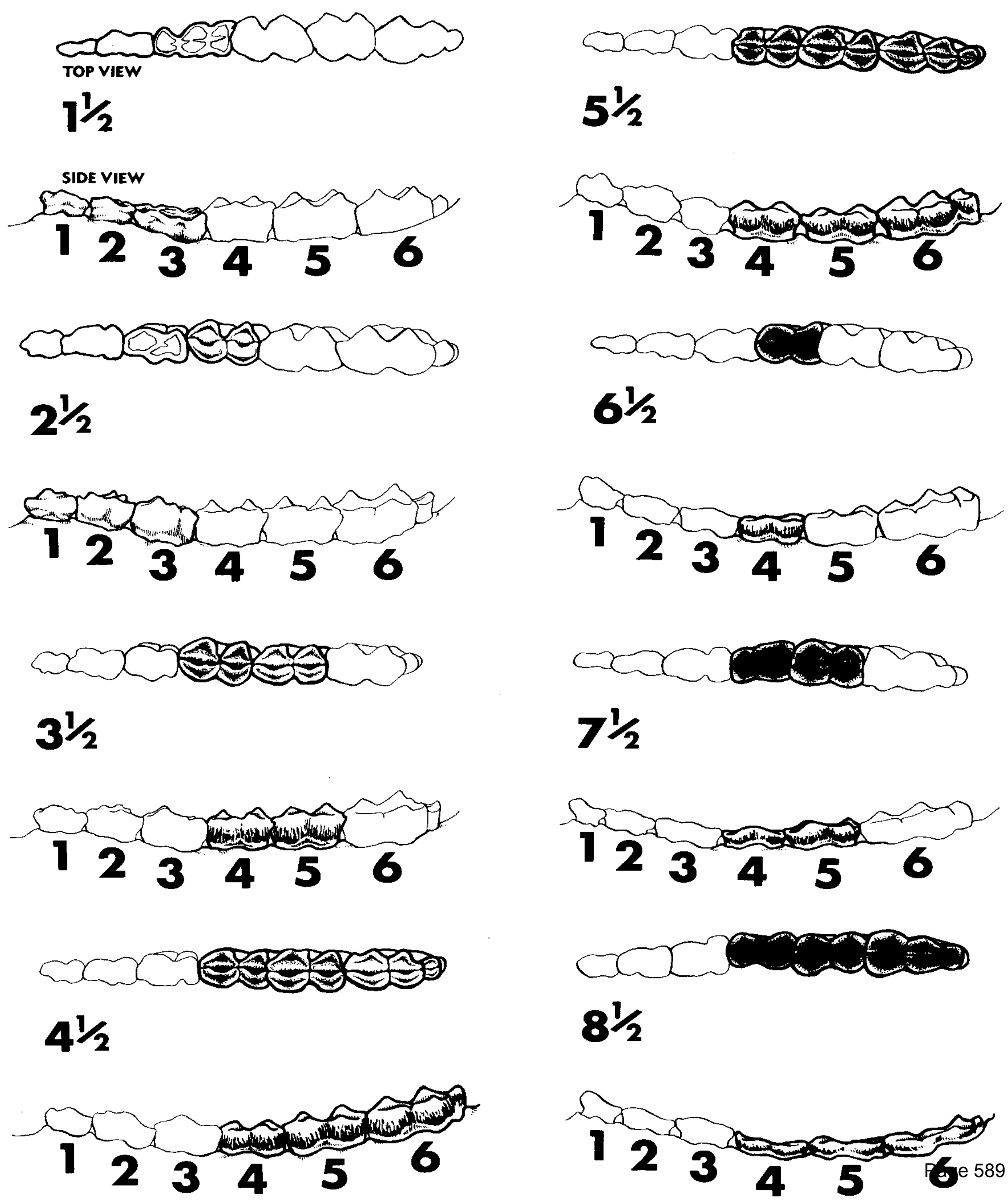
6 ½ year old: The first molar (tooth 4) is worn smooth, but teeth 5 and 6 are not smooth.

7 ½ year old: The first and second molars (teeth 4 and 5) are worn smooth, or tooth 5 may still have a small ridge left.

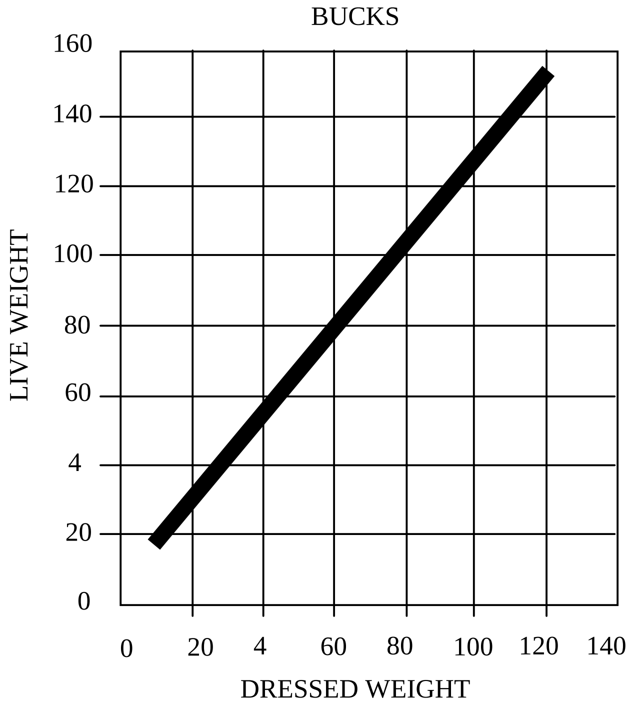
8 ½ year old: All molar teeth are worn smooth (teeth 4, 5, and 6 may still have a small ridge left.

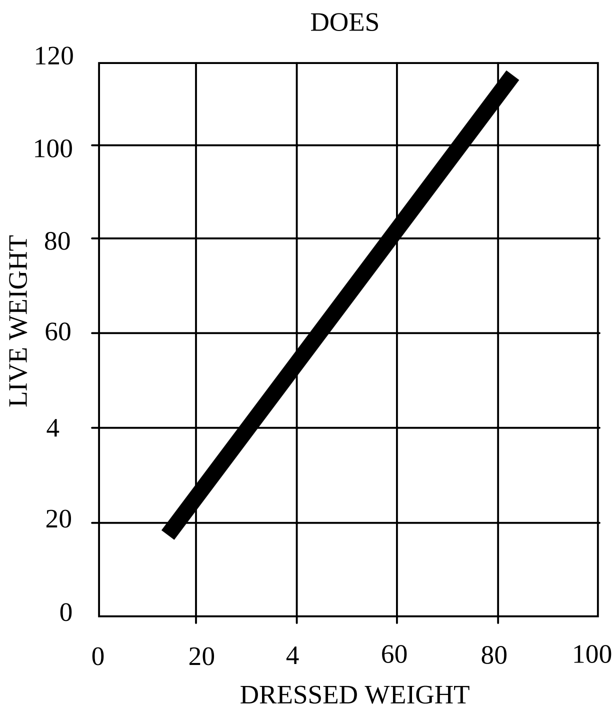
Older than 8 ½ year old: Unable to determine, because characteristic formations have all been worn smooth.

The primary factor governing antler formation is food supply. As deer grow older and their teeth wear flatter, food becomes harder and harder to chew. Body condition will drop and, simultaneously, so will antler development.



The Way to Weigh
by: Charles Ramsey & Melvin J. Anderegg





A pickup with two hunters drove up to the deer check station on the Kerr Wildlife Management Area. Both hunters climbed out, and walked around to the back of the truck and began unloading a couple of deer.

The first deer, a small doe, was tossed upon the table in the check station. Area personnel field dressed the deer and recorded descriptive measurements and weights. Then the doe was loaded back into the truck.

The second deer, a large buck, was lifted onto the table and the process of measuring and recording was repeated. Since the buck was already field dressed, only a dressed weight was taken – 106 pounds field dressed. How big was that deer on the hoof?

This question has been repeated so many times at the check station that two graphs were prepared to help with the answer. These graphs represent the weights taken from approximately 200 deer in good body condition killed on the Kerr Wildlife Management Area. Since these deer were typical of the Edwards Plateau, the graphs will be applicable for deer taken within the Hill Country. Although not as accurate, they are also good guides for deer taken from other areas of the state.

Dressed weight means "field dressed" with head, hide, and feet left on the carcass.

Great Trinity Forest Management Plan

Wildlife Management

Developing a Deer Management Plan

1

DEVELOPING A DEER MANAGEMENT PLAN

Michael Krueger, Technical Guidance Biologist , Lampasas
Jim Dillard, Technical Guidance Biologist, Mineral Wells

There are few successful ventures that did not start with a little forethought and planning. A "game plan" is needed for just about everything we do from cradle to grave to avert the "slings and arrows" of life. Things like family planning, financial planning, a health plan, and even a burial plan come to mind. And if you are a landowner, you know that good planning may be the difference between making it or breaking it financially. But, "if you don't write down the rules of your game, you'll always be playing a different game".

Developing a plan that addresses the proper management of wildlife populations and habitats on your land is no different. Whether you are making a living at it, or just trying to do the right thing for the land and wildlife, developing a plan of action is fundamental to success. But not everyone has all the "tools" in their tool chest to automatically know how to manage wildlife and wildlife habitat. There is more to it than most people think, and there are few shortcuts in this process.

Aldo Leopold said, "The urge to comprehend must precede the urge to reform." Consulting with a professional wildlife biologist and other resource management specialists will add an important perspective and dimension to proper planning of the wildlife and habitat resources on your land. Landowners should draw on the expertise of one or several resource professionals to help develop a wildlife management plan, one that is based on good science and sound population and habitat management principals. In Texas, on-site assistance is available from state and federal agencies such as the Texas Parks and Wildlife Department, Texas Agricultural Extension Service, and Natural Resources Conservation Service. These agencies do not charge a fee for their services, and complying with their recommendations is generally voluntary (a specific level of compliance may be required for participation in programs such as financial cost-share or the issuance of special permits). There are also non-governmental groups and private consultants available to provide wildlife management assistance to landowners. These others may charge fees for the services, but in return, they may be able to devote more time and provide more personalized service. In short, there are a number of wildlife management assistance options available to landowners. It doesn't hurt to go to several sources for help. You will likely find that the advice and recommendations offered by one will be very similar to that offered by another (singing the same verse of the same hymn), providing validation. But there also may be some variations (same hymn, but singing a different verse), presenting you with the opportunity (or dilemma) to pick and choose what you think works best for your particular situation.

Even if the white-tailed deer is your primary, or one and only, species of interest, be wary of anyone, regardless of who is consulted, who does not include a healthy dose of *ecosystem management philosophy* that goes beyond single species (i.e. deer) management. A good land stewardship philosophy should address the *whole* landscape as well as *all* the wildlife species that are found there, and the habitats they occupy.

WHY HAVE A WILDLIFE MANAGEMENT PLAN?

To be successful, a wildlife management plan must be *ecologically sound*, *economically practical* and *realistically attainable*. Practically every landowner has different ideas about what he or she wants to do with a piece of property, and different expectations for the land to meet their goals and objectives. And their financial resources range from shoestring budgets to bottomless pits. In reality, it is the *land* that will determine whether or not their goals and objectives are attainable. The Texas landscape is a lesson in biological diversity with 10 major ecological regions and many sub-regions and ecotones that are the end product of the geologic past, rainfall and temperature patterns, and land use history, both past and present. Plant communities in many areas have been altered over time by the cumulative influences of livestock grazing, fire or the lack thereof, and other land uses. Wildlife populations of the present are a reflection of the existing configuration of plant life on the landscape. Developing a wildlife management plan is primarily a matter of working with what you have and then trying to elicit responses from the land through implementation of proven sound land enhancement and management practices. The art and science of this process constitutes management, and it is an inexact science at best. "Trial and error" is often recommended to see what works and what doesn't. Flexibility is an important component of any wildlife management plan because responses to habitat enhancement practices from well-intentioned management schemes and strategies often "go astray". The concept of measuring twice and cutting once comes into play.

A wildlife management plan will provide a sense of direction for achieving long-term goals and objectives. It should outline a plan of action to follow so that wildlife, both game and nongame species, and their habitats are not adversely affected. Actions taken to enhance habitat or wildlife populations will result in reactions, many of which may be undetectable to the eye but significant to the welfare of something else.

In addition to providing a sense of direction to a landowner, a written wildlife management plan is required for participation in many state and federal land management cost-share incentive programs, and for the wildlife management use option of the open space tax valuation. Also, the Texas Parks and Wildlife Department requires a written plan as a prerequisite before landowners can participate in special hunting regulations, seasons, and bag limits - programs such as Managed Lands Deer Permits, Antlerless Deer and Spike Deer Control Permits, Trap, Transport and Transplant Permits, and Deer Management Permits.

ELEMENTS OF A WILDLIFE MANAGEMENT PLAN

The following subjects are the basic components of a wildlife management plan and some of the topics that should be addressed and documented. The list of topics is not necessarily all inclusive - every management plan is different, and the list may not fit every situation. Hopefully it is sufficient enough to understand the scope and concept of a wildlife management plan. A plan should include most of the following headings and subheadings, but should be customized for each particular situation.

Background Information -

- **Ownership** – Name, address, and phone number(s) of the landowner, as well as others (e.g. manager) who are responsible for assisting with making management decisions and implementing management practices.
- **Location of the Property** – County; distance and direction from the nearest city or town; roads used to access the property.

Statement of Goals and Objectives - This is basically a statement of where you want to go with your wildlife and habitat resources, providing direction for the specific things that will be needed to get there. Remember, the goals and objectives should reflect *ecological soundness*, *economic feasibility*, and *realistic attainability*. If they don't, you'll likely be disappointed with the results. The statement can be one sentence, or several one-line sentences. They may be general, but the more specific they are, the better they are for determining what needs to be done to achieve them. Some examples are:

- To properly manage habitat for native wildlife species for personal enjoyment and recreational use.
- To conduct habitat enhancement practices beneficial to native and migratory wildlife species.
- To produce trophy white-tailed deer and harvest mature bucks with 18 inch inside spreads and field dressed weights of 150 lbs. at 4 ½ years of age.
- To enhance habitat for maximum bobwhite quail production.
- To manage wildlife habitat for increased plant diversity and species composition.

Size of the Property and Acreage of General Habitat Types - The general habitat types found on the property should be categorized and expressed in number of acres. This should include acreage in croplands or cultivation, improved pastures, native grasslands, native brush or woodlands, wetlands or riparian areas, number and acres of ponds or lakes, etc. This will give you an idea of what you have to work with and help you determine if you are in the general ballpark of your goals and objectives. If you are interested in managing for white-tailed deer, it helps if you have white-tailed deer habitat. If your interest is in managing habitat for a diversity of songbirds, you would need a variety of habitat types.

Past History of Land Use and Wildlife - Knowledge of past land use practices is very important, and may help explain why the land looks like it does today. Knowing the history of hunting and wildlife harvest and the demographics of wildlife populations often explains present population levels of game animal species and the quality of those populations. Go as far back in time as possible. In some situations, such as a new ownership, the known history of management under the previous ownership may be minimal – in other situations it may be possible to go back several years, or generations. This section should include information such as:

- Habitat management practices conducted -
  - Where, when, and how much brush control has been implemented, and by what method (burning, mechanical, chemical, etc.).
  - Livestock grazing history (grazing intensity, classes of livestock, number of pastures, type of grazing system used – rotational, continuous, or none, etc.)
  - Range reseeding (species used, where and when), farming conducted in the past, etc.
  - Any other land use practices that may have had a direct impact on the land and plant life.
- History of wildlife populations and harvest of game animals. This is an area in the plan where you can establish a baseline to work from to measure the success of your management efforts.
  - Historic population densities, sex ratios, and species composition of wildlife determined from censuses.
  - Numbers of game animals harvested annually.
  - Field-dressed weights, antler measurements, and ages of harvested animals.
  - Hunting history (leased or non-leased, short-term or season-long, numbers of hunters, etc.)
  - Any stocking of wildlife species, including exotics, that may have occurred.

Current Situation – Provide information on:

- Vegetation management practices currently being conducted.
- Current livestock grazing practices (stocking rate, class of livestock, grazing system used, number and sizes of pastures, improved pastures used for grazing, etc.).
- How the property is currently hunted.
- Wildlife species present, including predators, exotic species, nongame and feral species.
- Amount of supplemental feeding and food plots currently being provided for wildlife.
- Amount and distribution of livestock and wildlife water sources (tanks, streams, wells).
- Habitat types and hunting practices on adjacent lands. Unless a property is high-fenced, species with large home ranges, such as deer, will liberally move back and forth across property boundaries. Documenting the habitat types, habitat management, and hunting practices on neighboring lands will help to identify liabilities, and assets, that will to some extent guide the management of your property. (Although you can't dictate or control how adjacent lands are managed, you can possibly influence management decisions by setting positive examples.)

Description of Habitat - Aerial photographs and topographic maps are very beneficial in identifying and assessing habitats and other features of the property. A combination of a desk review of photos and maps and an on-site field review should be used to gather information.

- Include information on elevations and topography, geologic features on the landscape, and the names of creeks, rivers or watershed drainages
- Since plants are a direct reflection of soil types, this section should include information on the different soil types or associations present on the property. Soils maps are readily available in soil surveys that have been published for most Texas counties by the Natural Resources Conservation Service. The "range site" designation associated with each soil type provides a description of the native plant community that can potentially grow on the site, which can be compared to the plant community that actually currently occurs. Knowing soil characteristics such as texture, water holding capacity, erosion hazard, and rooting depth are important for planning the locations of management practices such as food plots, brush control, and range reseeding.
- A professional wildlife biologist or resource specialist can be of assistance by identifying in detail the plant species composition present on the property. This description should be a comprehensive inventory of the trees and shrubs, forbs, and grass species present on the landscape. The species that are valuable as food and/or cover for wildlife should be identified. The plant list should include both native and introduced plants and identify any problem areas where invader species occur. The present degree of plant use by livestock and wildlife should be evaluated, and the overall condition of the plant community should be rated (i.e. fair, good, excellent). The adequacy of the density and distribution of wildlife cover should be evaluated.

Habitat Management Recommendations - This section is the "meat" of the plan. It identifies the habitat management practices specific to your property that address your goals and objectives, and are beneficial to the *entire spectrum* of wildlife and wildlife habitats that occur. Recommendations should be practices that affect wildlife food, cover, and water, and the proper arrangement of these habitat components. Refer to these recommendations often and update them as you progress with your management efforts. They may include but are not limited to the following:

- Livestock grazing recommendations (stocking rate, class of livestock, deferred-rotation grazing system, additional cross-fencing).
- Vegetation management recommendations (prescribed burning, mechanical brush control, proper use of herbicides, farming practices, rangeland reseeding, shallow disking to encourage forb growth, etc.).
- Watering facilities (development of additional livestock/wildlife water sources, or modification of existing facilities to better accommodate wildlife).

Featured Species - Your wildlife management plan should contain detailed information on the biology, life history and habitat requirements for the specific wildlife species (e.g. white-tailed deer, etc.) that are the intended primary beneficiaries of your management projects. Many species of wildlife have specific habitat requirements that are biologically driven. Knowledge of things like home range, territoriality, food habits, reproduction, population dynamics, longevity, seasonal movements, migration, and spatial requirements are fundamental to the management of each species.

Management recommendations should then be provided specifically for the featured species, in addition to and in conjunction with the overall management recommendations provided earlier in the plan. Specific recommendations could include:

- Supplemental Feeding / Food Plots **–** Feeding and food plots should not be viewed as a substitute for other proper land and wildlife management measures. Rather, as the term implies, these practices should be used to *supplement* the diet of the featured species and other wildlife during periods of stress or food shortages. The plan should identify the kind of feed to use, the type and number of feeders needed, and a schedule for distribution. Food plots almost require a plan of their own and can turn into downright farming if you want to do it right.
- Census Method(s) Used to Determine Population Density and Composition - This section should contain your plan for monitoring the populations of the featured species. List the census techniques to be used, when and where surveys are to be conducted, and method for data analysis. Here again, a professional wildlife biologist or resource specialist can assist you in determining how to gather and interpret this information.
- Recommendations for Harvest - For game species such as deer, turkey, and quail, hunting is an important part of the overall management program. *Annual* harvest recommendations, determined from *annual* census data, are especially necessary for deer to determine the appropriate harvest needed to maintain the desired density, sex ratio, and age structure of the deer population. A management plan featuring deer should address *general* deer harvest strategies to meet specific goals and objectives. However, the plan should stop short of making *specific* deer harvest recommendations – specific harvest rates should be developed annually and be based on current census data. The landowner should also put some forethought into the hunting strategy (numbers of hunters, etc.) that will be needed to achieve the desired harvest.
- Records Management - Good record keeping should be an important part of your wildlife and habitat management plan that will help you evaluate your efforts, environmentally as well as financially. Try to develop systematic measures to quantify the density and distribution of wildlife populations, habitat, plants, and land improvements. In addition, keep records on all wildlife surveys, population counts or casual observations throughout the year and develop trend information where possible on species abundance, distribution, and occurrence. Record data from game species harvested – numbers by sex, weights, antler measurements, and ages. Record the costs associated with any of the practices or conservation measures you use to enhance, maintain, or improve the land for reference or verification. Keeping good records is also recommended for documenting the land and wildlife management activities conducted if participating in the wildlife management use option of the open space tax valuation.

Other Species/Comments – This section can be devoted to "add-on" recommendations for the management of populations and habitats of other species on your property:

- Nongame species management (providing supplemental shelter such as birdhouses and brush piles, providing supplemental foods such as feeders, etc.).
- Control of predators and exotic and feral species of wildlife.

Species of Concern - In closing, your management plan should document if *species of concern* (that's the politically correct way of saying rare, threatened, or endangered species) occur on your property, or if there is suitable habitat indicating that a species of concern could potentially occur. The presence, or potential presence, of a federally-listed threatened or endangered species should not necessarily be considered a liability – good land stewardship, even if management is directed toward a game species or non-listed species, can be very compatible with maintaining habitat for a listed species, and vice versa. However, for every action there is a reaction that could either positively or negatively effect something in addition to the intended target. Professional resource specialists are legally obligated to not recommend any management practices that would knowingly harm a federally-listed species, or degrade its habitat. Likewise, landowners are obligated to not implement practices that could cause harm. Documenting the presence or potential presence of species of concern helps guide which management practices can be implemented, and those that should not be, to avoid causing adverse impacts.

PRIVATE LANDOWNERS ARE THE KEY

Since 97% of the land in the State of Texas is privately owned, the vast majority of the state's wildlife populations and wildlife habitats occur on private lands. Texas landowners are the key to maintaining and improving wildlife populations and habitats through the implementation of good, well informed, land stewardship practices.

Great Trinity Forest Management Plan

Wildlife Management

Guidelines for White-tailed Deer Management in the Cross-Timbers and Prairies Region of North Texas

TEXAS PARKS & WILDLIFE

GUIDELINES FOR WHITE-TAILED DEER MANAGEMENT IN THE CROSS-TIMBERS AND PRAIRIES REGION OF NORTH TEXAS

Jim Dillard, Technical Guidance Biologist, Mineral Wells

INTRODUCTION

As with other forms of agriculture enterprises, there are many problems and variables to consider and address to successfully manage white-tailed deer. It's fundamentally a matter of understanding white-tailed deer biology, their habitat and nutritional requirements, and setting clearly defined goals and objectives.

There are three broad areas that need to be addressed when developing and implementing a successful white-tailed deer management plan. They are: **habitat management, population management**, and **harvest management**. The following information will discuss and outline steps for management of free-ranging white-tailed deer herds in the Cross-Timbers and Prairies Region of north Texas.

THE CROSS-TIMBERS AND PRAIRIES ECOLOGICAL REGION

The Cross-Timbers and Prairies Ecological Region of north central Texas cover approximately **17.9 million acres**. Within this vast region there are five sub-regions or major land resource areas consisting of the **Eastern Cross-Timbers** (1 million acres), **Grand Prairie** (6.3 million acres), **West Cross-Timbers** (2.6 million acres), **North Central Prairies** (7 million acres), and **Central Rolling Red Prairies** (1 million acres). Populations of white-tailed deer are found throughout the region at varying densities dependent on the quantity and diversity of habitat, land use, livestock numbers and grazing intensity, seasonal rainfall patterns, deer harvest rates, and the degree of ***active*** management on the part of individual landowners.

Much of the **East** and **West Cross-Timbers** are post oak and blackjack oak woodlands. Historically, the **Grand Prairie** and **North Central Prairies** were predominately open grasslands with only scattered liveoak, but today juniper, mesquite, oak, and other native woody species have invaded much of that region. The **Central Rolling Red Prairies** are mostly open grasslands today with some invasion by mesquite. Habitat for white-tailed deer is not homogeneous throughout the region due to different soil types and geologic features on the landscape. Major soil associations of either sandy or clayey soils determine dominant woody vegetation. On the sandy, slightly acidic soils of the East and West Cross-Timbers, species such as post oak and blackjack oak are most common. On clayey soils of the Grand Prairie and North-Central Prairies, liveoak, Texas oak, mesquite, cedar elm and Ashe juniper are more dominant.

Major **woody plant species** that constitute the basic framework of white-tailed deer habitat are post oak, blackjack oak, liveoak, shinoak, Texas (Spanish) oak, bur oak, cedar elm, Ashe juniper, mesquite, bumelia, Texas ash, Mexican plum, blackhaw viburnum, possumhaw, roughleaf dogwood, Bois d'arc, Texas sophora, western soapberry, redbud, pecan, black willow, and cottonwood**.** Major **brush and understory woody species** include elbowbush, lotebush, prickly ash, flameleaf sumac, skunkbush sumac, greenbriar, grape, poison ivy, catclaw, agarita, pricklypear, tasajillo, coralberry, white honeysuckle and others. Many of these species provide components of the requirement for food and cover for white-tailed deer. Associated with these plant associations are a variety of annual and perennial grasses and forbs (weeds) that make up the overall habitat for white-tailed deer.

WHITE-TAILED DEER MANAGEMENT PROBLEMS IN THE CROSS-TIMBERS

Habitat for white-tailed deer in the Cross-Timbers and Prairies is not uniform in plant species composition or distribution. The quality of habitat varies considerable, often within short distances due to changes in soil type, terrains, and the degree or type of land use. Not all land within the Cross-Timbers and Prairies can carry high populations of deer, regardless of the quality of vegetation that may appear during different seasons of the year. Lush growth of woody browse species that are abundant during the spring and summer are starkly absent during the winter months. Dense postoak woodlands become deciduous deserts during winter when only forbs and winter grasses are available for deer forage. Droughts during this period of the year can result in short supplies of these preferred foods for deer.

Except during the breeding season, white-tailed deer generally live within a home range of approximately one square mile. Their daily movements within that home range throughout the year often results in movements into habitat found on more than one adjoining landowner. Consequently, landowners often "share" individual animals, particularly bucks during the rut. For this reason, the potential for successful white-tailed deer harvest management diminishes as landownership size decreases. As the size of individual ranches continues to decrease throughout the region, effective and meaningful management can be a challenge. **Fragmentation** of habitat often results when changing land uses occur on adjoining tracts of land that were once uniform rangelands or woodlands. Food and cover that are required to support a desired density of deer might no longer be present. Quality of habitat may also vary considerable on large ranches where overgrazing of rangelands by livestock occurs or white-tailed deer habitat is modified or lost to development of improved grass pastures or other land uses.

As landownership size decreases, the potential for over-harvest of white-tailed deer populations increases. Bucks that leave their home range during the rut will likely be exposed to added hunting pressure on adjoining ranches that may not have the same goals and objectives for harvest management that you have. Many ranches in the Cross-Timbers and Prairies do not set harvest recommendations for their hunters based on population management criteria or restrict the number of hunter on lands they lease out for hunting. Texas Parks and Wildlife encourages landowners to form cooperatives or local associations to develop common goals and objectives for white-tailed deer management.

There is no set acreage on which effective white-tailed deer management can be achieved in the Cross-Timbers and Prairies, although it goes without saying - the larger the better! Positive **habitat management** practices can be implemented on just about any size acreage. Effective **population** and **harvest management** will require ***a minimum of 2,000 to 2,500 acres***. Management strategies applied to any less acreage will be affected by the biological limiting factors of white-tailed deer for food, cover, space and the accumulative influences of actions taken by adjoining landowners.

WILDLIFE MANAGEMENT PLAN

Fundamental to managing white-tailed deer in the Cross-Timbers or anywhere else in the state, for that matter, is the development of a **wildlife management plan** written specifically for your ranch. It should clearly state your goals and objectives. In other words, where do you want to go with your white-tailed deer population and how are you going to get there. You can write your own wildlife management plan or call on the expertise of a professional resource specialist or wildlife biologist. Wildlife biologists with Texas Parks and Wildlife Department, working under the **Private Lands Enhancement Program**, are also available to assist you with preparing a wildlife management plan. A wildlife management plan should document all aspects of your land and wildlife management program. It should include a <u>description of the habitat</u>, <u>past history of wildlife and land use</u>, <u>current land management and livestock operations</u>, <u>information about current wildlife populations and harvest rates</u>, <u>and wildlife and habitat management practices to be conducted</u>. The key point is to write down your plan and refer to it often. Successful white-tailed deer management is a long-term endeavor, often requiring several years before noticeable changes take place. Because of the biology of white-tailed deer and their habits, their mobility, home range requirements, and other habitat needs, successful management is more practical on larger tracts of land. Cooperative agreements or associations between adjoining landowners is often the only way to successfully address white-tailed deer management on a scale necessary to implement habitat, population, and harvest management strategies.

FOOD - COVER - WATER - SPACE

Good habitat for white-tailed deer must meet their requirements for **food - cover - water -** and **space.** The diet of white-tailed deer consist primarily of **forbs** (broadleaf herbaceous plants), **browse** (leaves and stems of woody plants), **mast** (acorns, nuts, fruits), and **grass** (primarily cool season or winter grass species). In addition, deer use cultivated crops that occur within their home ranges when available and may cause depredation problems to landowners. <u>**Forbs**</u> are high in protein and are sought after by deer throughout the year when they are available. <u>**Browse**</u> is important during the spring and summer months, particularly during late summer when dry conditions reduce availability of forbs. In the Cross-Timbers, winter browse is lacking and in many areas totally absent. <u>**Mast**</u> is readily eaten when available but generally is an unreliable or short-term food source. **<u>Grasses</u>** normally make up less than 5% of the diet of white-tailed deer. In addition, deer use cultivated crops that occur within their home ranges when they are available and may cause depredation problems to landowners. Winter crops of wheat and oats are important components of white-tailed deer habitat in many areas of the Cross-Timbers and Prairies and serve to improve the habitability of marginal habitats for white-tailed deer. Deer also use spring and summer crops such as peanuts, milo and other sorghum varieties, and fruit and vegetable crops such as watermelons, cantaloupes, beans, peaches, grapes, and ornamental plants.

<u>Quality</u> and <u>quantity</u> of **browse** on the landscape in the Cross-Timbers and Prairies is probably the most reliable indicator of good deer habitat conditions throughout the year. In the Cross-Timbers and Prairies Region, important woody browse plants are **skunkbush sumac, hackberry, cedar elm, shinoak, post oak, blackjack oak, flameleaf sumac, Texas redbud, greenbriar,** and **bumelia.** Lands supporting growth of a variety of these species will have a higher carrying capacity for white-tailed deer than those with only a few.

Cover provides security from predators and exposure to disturbances from other environmental factors and weather. The best cover for white-tailed deer is a pattern or mosaic of woody trees and brush interspersed with openings at an approximate **2 to 1 ratio of open area to woody cover.** Clumps or strips of brush should be wide and dense enough during the winter dormant period so that deer can't see through them. White-tailed deer also require space and secure areas for escape from predators and fawning. Habitat management practices that increase the amount of "edge" within a deer's home range are also beneficial.

The presence of adequate surface **water** is an important component of white-tailed deer habitat in the Cross-Timbers. Deer will consume 3-6 quarts of water per day if available and depending on air temperature. Deer also absorb water contained in plants and can produce metabolic water, which is produced in their cells as part of metabolism. Development of additional surface water sources will also improve habitat for white-tailed deer.

HABITAT MANAGEMENT

Properly managing habitat for white-tailed deer includes a series of planned actions and strategies designed to provide for the biological and environmental needs of a healthy white-tailed deer herd. There is a number of "tools" available to land managers to help manage the habitat required by deer. Aldo Leopold, known as the "father of wildlife management", promoted the use of "the cow, the ax, the plow, fire and the gun" as tools available to the wildlife manager. Without going into great detail, I will mention some of the management practices most important for white-tailed deer habitat management.

Proper **livestock management** is the most important aspect of land management to be addressed on most ranches in the Cross-Timbers. Significant improvement in available forage used by deer and other wildlife species can be achieved with proper stocking rates, use of rotational grazing systems and pasture deferments, use of compatible classes of livestock, and short duration grazing. If **brush management** is necessary, a concerted effort should be made to consider food and cover requirements of wildlife prior to conducting brush control. Individual plant treatment systems such as grubbing or spot treatment with herbicides is better than broadcasting herbicides for total coverage. In the Cross-Timbers, most brush management efforts are directed toward Ashe juniper, mesquite, pricklypear, and eastern red cedar. **Range management** practices that promote growth of native grasses and seasonally important annual and perennial forbs will benefit white-tailed deer. **Fire** is another tool that, when properly applied to the land, can result in greater plant diversity, reduce invasion by undesirable woody plants such as juniper, mesquite, and pricklypear, and improve soil fertility.

Food plots may be used to seasonally supplement the diets of white-tailed deer within their habitat. They are expensive to develop and maintain and should not be used as a substitute for other neglected land management practices. Generally speaking, "when you need them you can't grow them, when you don't, you can." Food plots can be divided into two categories - **warm season** and **cool season** and either annual or perennial plants. **Warm season** planting of crops such as annual legumes (peas), milo and other sorghum varieties, soybeans, and recently lablab are commonly planted in the Cross-Timbers. **Cool season** crops of wheat, oats, clovers and vetch varieties, and Austrian winterpeas can be planted in food plots. Literature is available on planting food plots in the Cross-Timbers from Texas Parks and Wildlife.

The use of **supplemental feeding** is increasing in popularity by landowners in the Cross-Timbers. Like food plots, supplemental feeding should not be used as a substitute for deficiencies in the habitat. Use of supplemental feeding should only be used to supplement the natural forage and diet of deer, not replace it. Deer are selective feeders and will normally only use supplemental food sources during periods of stress or when natural forage is in short supply. Deer may completely stop using supplemental feeders during acorn drop or spring green up.

Supplemental feed should be a compete ration developed specifically for white-tailed deer containing a minimum of **16% protein**. A number of commercial feeds have been developed and are available. Feed should be fed from feeder systems designed specifically for feeding deer. Bulk feeders with timed-release mechanisms are the best. Free-choice feeders should be covered to prevent water damage and contamination. Corn is commonly fed to deer by many landowners and hunters. It is low in protein but high in carbohydrates. Be sure any corn you feed deer has been tested for **aflatoxin**, a fungi producing toxin, and contains no more that **20 parts per billion**.

POPULATION MANAGEMENT

Once your goals and objectives for habitat management have been developed and initiated, consideration must be given to strategies for **population management**. Basically, you must determine the quantity and quality of white-tailed deer you want to support on your ranch. How many deer can your habitat support and what do you want them to look like? The physical appearance of a white-tailed deer is the result of three things - **its nutrition, its age,** and **its genetics**. You will have limited effect on the genetics aspect of a free-ranging deer herd. Management efforts should be directed toward habitat, nutrition, and age-class improvement of the deer herd.

Total counts of free-ranging white-tailed deer herds are not possible using any type of deer census technique. Deer survey techniques provide estimates of population density expressed as **acres per deer.** They also provide information on the sex and age ratio of the population and trends in population fluctuation from year to year. The number of healthy deer that habitat can support on a year around basis is referred to as **carrying capacity**. Carrying capacity varies throughout the Cross-Timbers and no set figure can be applied to all deer habitats. Carrying capacity estimates ranges from **one deer to 10-12 acres** on good habitat in the Cross-Timbers to as little as **one deer per 25-30 acres or greater** on poorer habitats. The **sex ratio** of free ranging deer herds in the Cross-Timbers should be somewhere around **2.00 to 2.50 does per buck.** With more intensive management, that ratio can be reduced. A ratio of around **0.75 fawns per doe** observed during late summer and early fall is an indication of healthy reproductive deer herd.

White-tailed deer density, sex-ratio, and herd composition can be determined by using a combination of **deer spotlight surveys** and **daylight herd composition counts** conducted during **the August-September-October** period annually. A minimum of **three spotlight surveys** should be conducted annually during this period to determine average number of acres per deer. Spotlight surveys are an "area transect" of a determined acreage on which the total number of deer are counted. **Herd composition** is determined by identifying as many bucks - does - fawns in the population during this same time period from daylight counts to determine the ratio of the sex and age-classes in the population. Without an estimate of the total deer density in acres per deer and information on the ratio of bucks to does and fawn per doe, no definitive harvest recommendations can be made. Texas Parks and Wildlife has literature available on how to conduct these two types of surveys. Landowners under a TPWD wildlife management plan receive assistance on how to conduct these surveys and how to use the data collected for determining harvest rates and achieving of your goals and objectives.

Aerial helicopter deer surveys may also be used to survey deer populations. Researchers in South Texas have found such surveys unreliable for determining actual deer density, sex ratios, and fawn production estimates. If aerial helicopter surveys are used in the Cross-Timbers and Prairies, they must be made during late winter after leaves on deciduous trees have fallen and visibility conditions improve. Fawns and spike bucks are difficult to identify by late winter and some bucks may have shed antlers. Also, post-season counts do not provide the timely population data necessary to formulate harvest recommendations.

HAVEST MANAGEMENT

Once you have an estimate of the density and herd composition of your deer population, decisions must be made about how many, if any, deer should be harvested to meet your goals and objectives. How many and which bucks - how many does - and how many hunters should you have? This is the point where you make the connection with hunters. Hunters serve a very important role in white-tailed deer management programs. They can help you achieve your goals and objectives by harvesting the recommended number of bucks and does from the population. If you do not have "good" hunters that will cooperate with you on your management program, your chances of success will be diminished. When possible, involve your hunters in your overall management program and keep them informed about your goals and objectives. Not all hunters are able to identify mature age-class bucks and others may be reluctant to kill antlerless deer.

Achieving your goals and objectives may be impossible without clear communication between you and your hunters. The number of hunters you have on your ranch should be based on the number of deer you want harvested. Determine how many bucks and does you want removed from your land based on annual deer surveys and herd composition counts **before** you lease out hunting rights or renew lease agreements with existing hunters. That information can also be incorporated into the lease agreement so hunters will know what is expected.

HARVEST MANAGEMENT STRATEGIES

Your **harvest management** should include several basic strategies to harvesting deer. It should specify what type of bucks you want to produce and harvest. If producing mature age-class bucks is your goal then only mature age-class bucks should be killed. Deer densities must be maintained below or near estimated carrying capacity or other aspects of your management program such as body weights, reproduction, or habitat will be affected. You must also harvest the proper number of bucks or does to achieve your desired buck to doe ratio goal.

HARVEST RATES FOR BUCKS

If your management **strategy** and **goal** is to produce **mature age-class bucks** for harvest, you must educate your hunters about selectively hunting that type of animal and passing up young bucks. Bucks do not mature until they are over 4 years of age. Killing them prior to that point will defeat your goal. To produce **mature age bucks**, total buck harvest should not exceed **20% of the estimated buck population**, including spikes. If you goal is to produce **some mature age class bucks** in the population, harvest approximately **30% of the estimated buck population**, here again hunters selecting only mature age-class animals. For **maximum harvest** of bucks, **40-50% of the estimated buck population** can be harvested. Under this harvest strategy, few mature age-class animals will be available for harvest. Deer populations that are **at carrying capacity** should be harvested at the rate of approximately 3**0% of the total estimated population** to allow for annual reproduction that will be added to the population.

Spike-antlered bucks are the result of the influence of age, nutrition, genetics, or combination of these factors. Studies on the Kerr Wildlife Management Area showed that "most deer which are spike-antlered as yearlings will not be spike-antlered in later years, but will continue to be inferior to their fork-antlered cohorts". Of 144 white-tailed deer bucks from the Kerr Wildlife Management Area, 62% of the fork-antlered bucks as yearlings scored in excess of 120 B&C at 4 ½ years of age whereas only 2.3% of spike-antlered yearlings had similar scores at that age. The majority of spikes in the Cross-Timbers and Prairies Region are restricted to the 1 ½ year age-class. **Texas Parks and Wildlife Department recommends that spikes not be protected from harvest and be included in any buck harvest recommendation as part of the total recommended buck harvest.** If you have a choice between killing a young fork-antlered buck and a spike - take the spike or another antlerless deer.

The introduction of deer on ranches in the Cross-Timbers and Prairies from other parts of Texas or other states is **not** recommended as a means to improve the genetic make up of free ranging deer herds. Most native white-tailed deer found in the Cross-Timbers and Prairies that are provided good habit and nutrition and are allowed to reach mature age-classes exhibit antler and body characteristics acceptable to most landowners and hunters. The Cross-Timbers and Prairies Region ranks second only to South Texas in the number of entries in the annual Texas Big Game Awards Program that recognize quality native deer produced on private ranches in Texas. Deer moved from other area may not have natural immunity to diseases that resident animals have. The probability that the genes of a few imported bucks will change the genetic make up of a free ranging deer herd is not likely. Fifty percent of the genetic make up for antlers characteristics are contributed by the female.

WHITE-TAILED DEER BREEDING CHRONOLOGY

Texas Parks and Wildlife conducted research between 1991-1993 to determine the chronology of breeding activity by white-tailed deer throughout the state. In the **Cross-Timbers**, fetus measurement taken from 296 does over the three-year period indicated that the **peak conception date for white-tailed deer was November 16th.** Conception ranged from as early as **October 13** to as late as **December 17th.**

INTERPRETING HARVEST RECORDS

Plan in advance and work with your hunters to **require** that certain biological data be collected for deer they kill on your ranch. If you are not actively involved in this process it is unlikely to get done. Basic biological data that should be collected from **each** deer harvested under a management plan is **date of kill**, **location** (pasture), **age** (1 ½, 2 ½ ,etc.), **field dressed weight** (in pounds), **antler measurement** from bucks including **number of points** (one inch or longer), **inside spread**, length of each **main beam, circumference of each base**, **general physical condition** (good, fair or poor) and **does lactating** (yes or no).. Provide scales, forms for recording data, jaw extractors for removing and saving jawbones for later aging, freezers for storing jawbones or other specimens. At the end of the season, all data should be **averaged by age-class**. Physical characteristics such as body weights and antler size are age-related. Analysis of long-term data collected and averaged by age-class will allow you to measure the success of your management efforts and detect annual trends in those white-tailed deer biological features you want to improve or increase. Without a system for evaluating your harvested animals it will be difficult to measure your success.

CONCLUSION

In summary, before you embark on a deer management program, develop a **written wildlife management plan** and outline what you want to do, how you plan to get there, and what results you expect to achieve. All successful management programs for white-tailed deer must address **habitat management, population management,** and **harvest management.** Texas Parks and Wildlife Department supports land and wildlife management on an ecosystem approach, where the long-term management efforts will benefit not only white-tailed deer, but also a variety of other wildlife species on your land. We recognize that without the conservation and management efforts of private landowners in this state that own 97% of the land, the futures of Texas wildlife are in jeopardy.

<u>Great Trinity Forest Management Plan</u>

Wildlife Management

Deer Management Within Suburban Areas

DEER MANAGEMENT WITHIN SUBURBAN AREAS

Greg Creacy, Texas Parks and Wildlife Department
April 2006

INTRODUCTION

White-tailed deer populations within the United States have undergone tremendous change within the past two centuries. Unregulated market hunting and extensive habitat modification resulted in the near extirpation of the species by the early 1900's. However, white-tailed deer numbers have dramatically increased during the past few decades. Natural habitat succession, deer restoration programs, intensive management efforts, predator control programs, public education campaigns, and the deer's natural adaptive abilities have all contributed to historic high deer densities across the United States. Currently, an estimated 4 million deer reside in Texas, alone. In many areas of the state, deer population densities have exceeded the land's ability to sustain them. In other areas, deer densities have exceeded society's ability to tolerate them. These unnaturally high deer densities can present significant ecological, social, and economic problems for a variety of stakeholders.

Nowhere are these problems more evident than in today's suburbs. As citizens increasingly seek refuge from urban life, they create a demand for residential areas that incorporate elements of the land's natural surroundings. These remnant natural habitat features commonly include patches or mosaics of undeveloped habitat utilized for visual obstruction, recreational areas, or erosion control. This highly fragmented landscape is the preferred habitat structure of white-tailed deer. Residential developments also possess a variety of planted trees and shrubs, and large portions of the landscape are watered and fertilized. In many cases, the nutritional quality of the food is not as high as that in rural areas, but the quantity of food is high. Thus, this enhanced landscape provides year-around stable living conditions for deer, as opposed to fluctuations in forage availability on natural ranges.

Another factor leading to suburban deer overabundance is the scarcity of predators within these habitats. Modern deer populations on natural ranges are maintained at suitable levels largely by fawn predation. The reduction of predators within less natural, suburban habitats contributes to unusually high fawn survival rates. Additionally, recreational hunting is not allowed within most residential areas. In rural areas across the United States where deer predators have been eliminated, recreational hunting has served to create a balance between deer populations and their available habitats.

Lastly, suburban deer overabundance presents unique challenges and circumstances to deer managers. While the biological constraints of deer herds are commonly considered when managing rural deer populations, suburban deer overabundance is usually solely a reflection of human values. When deer numbers approach or exceed human tolerance levels, they may be considered overabundant.

Problems Associated with Suburban Deer Overabundance:

1. **Deer/Vehicle Collisions**
   Each year in the US, about 29,000 people are injured and more than 200 people are killed in deer/vehicle collisions. An estimated 1.5 million deer are killed, annually, resulting in more than $ 1 billion in property damage (Conover 2002).
2. **Lyme Disease**
   White-tailed deer are the primary hosts for black-legged ticks, or deer ticks (*Ixodes* sp.). These ticks are responsible for transmitting the causative agent of Lyme disease to humans. According to Conover (2002), more than 13,000 cases of Lyme disease are reported, annually. Research has shown increased tick abundance and more human disease occurrences in areas with high deer densities.
3. **Landscape/Garden Damage**
   Many trees, shrubs, vines, and herbs planted within residential landscapes are highly preferred by white-tailed deer. Of course, severity of landscape damage is directly proportional to deer population density. It has been estimated that residential landscape damage in the U.S. may exceed $250 million per year (Conover 2002).
4. **Habitat Degradation**
   Excessive deer densities are known to cause long-term damage to wildlife habitats. Overabundant deer herds can extirpate preferred plant species, alter habitat structures, and disrupt natural succession of plant communities.
5. **Declining Deer Herd Health**
   As deer populations overutilize available resources, herd health inevitably declines. Increased parasite loads and declines in body weight, antler production, and fawn recruitment are often followed by large-scale deer "die-offs".
6. **Public Safety**
   Aggressive encounters between people and deer are relatively uncommon. Nonetheless, 5 – 10 people are killed annually in the U.S. by aggressive bucks (Conover 2002).

Obstacles Associated with Suburban Deer Population Control:

1. **Aesthetics**
   Many people enjoy wildlife watching within their neighborhoods. Their satisfaction derived from watching deer seems directly proportional to the number of deer observed. Furthermore, most residents have the misconception that deer control measures will result in deer eradication, thus eliminating wildlife watching opportunities.
2. **Safety and Liability Concerns**
   Harvesting or capturing animals within populated areas may create safety concerns for residents. While many safety concerns are only perceived, rather than real, special safety precautions must be addressed before deer control measures are initiated.
3. **Conflicting Social Attitudes and Perceptions**
   Controlling deer populations within residential areas involves numerous stakeholders. These stakeholders often present disparate views and opinions regarding control measures. Some people consider a deer's life more important than minor inconveniences and potential health and safety risks caused by deer. Others value human life and comfort more than deer. These people commonly view wildlife as a resource to be managed and utilized by humans.
4. **Hunting and/or Firearm Restrictions**
   Local ordinances and/or policies regarding hunting and the discharge of firearms may be obstacles to implementing deer control measures.
5. **Public Relations Concerns**
   Appointed decision makers within city governments, community associations, or development organizations are often hesitant to make controversial or divisive decisions.

MANAGEMENT OPTIONS

When addressing suburban deer problems, the advantages and disadvantages of all available deer management techniques must be evaluated. Differing circumstances among suburban communities will result in varied approaches to solving the problem. Furthermore, it is likely that a combination of management techniques will be necessary to achieve desired results (DeNicola et al. 2000). Involved stakeholders should be made aware that suburban deer management objectives are achievable, but they are often difficult and costly. Deer control measures require community input, as well as considerable long-term planning and commitment. The costs of suburban deer management should always be compared to potential benefits such as reduced deer/vehicle accidents, improved human safety, and decreased landscape/garden damage (Doerr et al. 2001).

It is important for communities to develop measurable long-term goals and objectives as part of a comprehensive deer management plan before implementing deer control measures. Objectives based on deer abundance could be evaluated with standard deer survey techniques such as survey transects or time/area counts. Indicators such as frequency of deer/vehicle collisions, number of reported deer complaints, or predetermined reductions in landscape damage, could be used to measure cultural objectives. Stakeholders should understand that the total elimination of the problem (or the deer herd) is neither practical nor achievable in most cases. Rather, the goal should be related to the reduction of deer-human conflicts to an acceptable level (DeNicola et al. 2000).

Managing an overabundant deer population should be accomplished in two phases (DeNicola et al. 2000). First, the **Initial Reduction Phase** is implemented to remove large numbers of deer from an overabundant herd during a short period of time to achieve desired deer densities. Deer managers have learned that deer herd reduction measures that remove less than 50% of the estimated population typically do not provide significant relief from density-related problems. After completion of the initial phase, a **Maintenance Phase** includes long-term efforts to maintain deer densities at target levels. Many protected areas include deer-proof fencing projects in their long-term maintenance program in order to restrict the ingress of additional deer and gain more control over their deer herd. Most importantly, deer managers should have long-term deer management plans in place before initiating deer herd reduction operations.

Deer management costs can be highly variable depending on available labor, deer densities, management objectives, and other site-specific factors. Additionally, it has been shown that the cost of removing, treating, or otherwise managing deer increases as deer management programs progress (Rudolph et al. 2000). As deer numbers decrease, it takes increased effort and resources to affect the remaining population. DeNicola et al. (2000) states, “High costs associated with diminishing returns may prevent achieving population goals with some techniques.”

Of course, deer managers must comply with applicable state wildlife regulations, city ordinances, and community policies while conducting deer control measures. Lethal control measures commonly require the approval of city government and special authorization from Texas Parks and Wildlife Department.

1. HUNTING

For decades, regulated hunting has proven to be an ecologically sound, socially beneficial, and fiscally responsible method of managing rural deer populations (NH Fish and Game Dept. 1996). Recently, as deer overabundance issues have become more common, controlled hunts have been successful in several protected areas across the United States (DeNicola et al. 2000). Controlled hunting sometimes results in lower deer harvest rates when compared to other deer control measures. However, this technique has also been shown to increase deer wariness toward humans, possibly alleviating some nuisance problems (Sage et al. 1983, Kilpatrick and Lima 1999).

Hunting is the only method with potential to generate revenue for landowners or communities. Costs associated with controlled hunts (support staff wages, administration, and equipment) usually range from $75 to $100 per harvested deer in Texas, which can be recovered with hunter fees. The additional provision of hunting opportunity for area residents may also be a positive consideration. Nonetheless, many additional factors must be addressed before implementing this practice within suburban areas. Some of these additional factors may include: safety considerations, competing land-use priorities, legal constraints, and social values.

When developing plans for a hunting program, several factors should be considered when selecting a hunting technique. Considerations include property size and layout, number of hunters, weapon type, deer densities, and any other local factors which could affect the success of the program or safety of the residents. Regardless of weapon type, elevated hunting stands are commonly used so that the ground is used as a backstop for the projectile (DeNicola et al. 2000). Baited areas are also utilized to concentrate deer and improve hunter success.

Archery hunting has been the preferred method within many residential areas, due to the weapon's limited shooting range and relative silence (Lund 1997, Ver Steeg et al. 1995). However, Texas Parks and Wildlife Department's public deer hunt data suggests that hunter success is usually much lower with this method compared to firearms hunting. Additionally, archery hunting is commonly perceived to result in higher wounding losses and increased travel distances before deer succumb to their injury (Kilpatrick and Walter 1999). This could lead to possible conflicts with nearby residents and should be considered prior to employing this technique.

Shotgun hunting is another alternative to high-velocity rifles, due to the weapon's limited effective range (Kilpatrick et al. 2002). Hunter success can be improved with this method by employing rifled gun barrels with sights or scopes (DeNicola et al. 2000).

<u>Possible hunting program options/suggestions:</u>

- **Allow each homeowner to hunt deer, if they wish.**
- **Have a lotto drawing for a designated number of hunters.**
- **Mandate a proficiency test before any hunter is allowed to hunt (target shoot test).**
- **Mandate an orientation/safety meeting for all hunters.**
- **Mandatory check in/check out for all hunters.**
- **Designate specific hunt areas or shooting lanes.**
- **Allow hunting from elevated stand, only.**
- **Sign agreement to harvest 2 does before harvesting a buck.**

2. SHARPSHOOTING

Many suburban communities and protected areas across the United States have employed trained and experienced sharpshooters to reduce or control deer numbers. Sharpshooting has been demonstrated as an effective technique to discreetly remove significant numbers of deer from targeted areas within a relatively short time period (Butfiloski et al. 1997, DeNicola et al. 2000). Some protected areas and parks have utilized on-staff conservation officers for sharpshooting programs. Others have hired and trained off-duty police officers or employed specialized contractors to conduct sharpshooting operations (DeNicola et al. 1997, Frost et al. 1997, Jordan et al. 1995, and Stradtmann et al. 1995). Specialized sharpshooting contractors commonly utilize night-vision equipment, suppressed rifles, and elevated stands to harvest deer at baited areas. Regardless of the chosen method, sharpshooters should be selected based on experience, training, and efficiency at harvesting deer. There is most likely a significant difference in harvest efficiency among shooters.

Sharpshooter operations may cost $100 - $250 per deer. This cost includes: sharpshooter and support staff wages, administration, bait, equipment, etc. Project costs are significantly reduced if landowners handle arrangements for transporting, processing, and donating the meat.

Sharpshooter operations are often not authorized by state natural resource agencies unless landowners have taken steps toward long-term deer control (i.e., constructing deer-proof fence around area).

Possible Sharpshooting Program Options/Suggestions (adapted from DeNicola et al. 2000):

- **Use baits for attracting deer to designated areas prior to removal efforts.** Research has shown that sharpshooting over bait is more productive than opportunistic sharpshooting.
- **Shoot deer from portable tree stands, ground blinds, or from vehicles during day or night.**
- **When possible, select head (brain) or neck (spine) shots to ensure quick and humane death.** Cranial shots are very humane and approved by the American Veterinary Association as an acceptable means to dispatch animals.
- **Process deer in a closed and sheltered facility.**
- **Donate meat to food banks for distribution to needy people in the community.**

3. TRAP AND TRANSLOCATE

Trap and translocation efforts have been utilized by numerous communities and protected areas across the United States. This technique's popularity has been a result of the general public's perception that it poses no risk to human safety and is a non-lethal solution to deer overabundance problems (Stout et al. 1997). However, very few deer managers have accomplished population reduction goals with this method. Capture and translocation has been shown to be ineffective and costly (Jones and Witham 1990). Furthermore, translocated deer have demonstrated high mortality rates resulting from: capture-related injuries, capture myopathy (trapping stress), unfamiliarity with the release site, human activities, and encounters with new mortality agents (Beringer et al. 1996, Jones and Witham 1990). Translocated deer from residential areas usually demonstrate reduced flight distances when disturbed and a preference for roadsides and open lawns. Studies have shown that as many as 25% of translocated deer die within the first two months of trapping/translocation, and more than 65% of deer may not survive longer than one year (Beringer et al. 1996, Jones and Witham 1990, NH Fish and Game Dept. 1996, O'Bryan and McCullough 1985).

There are several other factors, which contribute to this technique's impracticality. Trapping success is often related to habitat type. Deer are less attracted to artificial baits in areas with adequate forage. Deer also become increasingly wary of trapping mechanisms as projects progress. Translocation efforts are further complicated by the lack of suitable release sites. Most habitats within the species' native range are already saturated with deer, and cannot withstand supplemental stockings without risking damage to the habitats. Lastly, wildlife diseases are another concern when deer are moved from one location to another. This technique has the potential to spread harmful and contagious pathogens from one deer population to another.

Trapping operations can range from $150 - $500 per deer. Trap and translocation costs for Lake Way subdivision near Austin, Texas cost $150 per deer in 2000. The donor property usually encumbers the cost. However, receiving landowners occasionally share trap and translocation expenses.

4. TRAP AND EUTHANASIA

Deer can be captured with a variety of traps or nets. They can be driven, or herded, into the entrapments or attracted with bait. Following capture, deer are euthanized either on or off site, most commonly with a bolt-gun. Texas Parks and Wildlife Department recently approved this method to control overabundant deer herds. However, trap and euthanasia is not currently authorized by all State natural resource agencies, and has been assessed or considered in only a few locations within the United States. This technique may be preferred in areas where firearms discharge is a major concern. Additionally, it has been proposed as a complement to sharpshooting programs in areas with extremely high deer densities.

Most deer control methods that involve live-trapping are inefficient and cost-prohibitive. Refer to **Section 3. Trap and Translocate**, above.

5. FENCING

Fencing is a method most protected areas utilize for effective and long-term deer control. This method prevents the ingress of additional deer and aids with local population control measures. However, many residents may perceive fence construction as a distraction from the aesthetics of their community. Other difficulties encountered with this technique may include road, stream, and utility right's-of-way that traverse the proposed fence line. In some cases, multiple ownership of proposed fence lines may also be an obstacle to fence construction.

Most effective fence designs include mesh or high-tensile wire at least 8 to 9 feet in height in order to restrict deer movements. Private contractors usually charge between $10,000 and $15,000 per mile to construct these fences. Construction costs increase if fence lines require clearing. While initial fence construction costs are high, long-term costs of this deer control method are comparable to other techniques. For example, if 100 deer are prevented from entering a one-mile section of the property during a 10-year period, the fence has saved landowners $10,000 to $25,000 in sharpshooting program expenditures.

In some situations, partial fences can be constructed along deer travel corridors to restrict the ingress of additional deer. Some properties begin fencing projects on these highly traveled borders and construct additional sections as funds become available.

6. FERTILITY CONTROL AGENTS

Researchers have been experimenting with fertility control agents for free-ranging deer for many years. However, past studies have indicated the use of these drugs to be impractical and cost-prohibitive (NH Fish and Game Dept. 1996, Rudolph et al. 2000). Due to extensive man-hour requirements, costs per treated female have been as much as $550 for the initial treatment and up to $175 for annual booster treatments. Furthermore, no effective fertility control agents are likely to be developed in the near future for suburban deer herds (DeNicola et al. 2000). Regardless, residents often request this technique as a way to solve nuisance deer problems humanely, safely, and non-lethally.

Researchers commonly separate deer fertility control agents into two groups (DeNicola et al. 2000, Waddell et al. 2001): (1) contraceptive agents that prevent conception and (2) abortion chemicals that terminate pregnancy. Fertility agents are typically administered remotely with a rifle. Oral contraceptives are not feasible due to the inability to select for a target animal, lack of dosage control, and difficulties with absorption of the active ingredient (NH Fish and Game Dept. 1996, Rudolph et al. 2000).

Obstacles to Effective Fertility Control:

1. **Deer Population Must Be "Closed"**
   Treated deer populations must be isolated, or closed, from adjacent populations. Deer immigration from adjoining properties would negate any fertility control efforts within the treated area. New immigrants would not have been exposed to the fertility agents. Additionally, chemicals used to control white-tailed deer fertility are experimental and not FDA-approved for human consumption. A treated deer in an "open" population could leave the property, where it could be subject to human harvest and consumption.
2. **Population Must Be Small**
   Because annual mortality rates for suburban deer populations are often very low, a large proportion of the females (70 to 90 percent) must be treated to curb or reduce population growth. Since oral fertility agents are not an option, the majority of females within the population must be captured, marked, and treated with the drug. With some drugs, sequential treatments must be administered to each female (Rudolph et al. 2000)
3. **Population Must Be At Target Level**
   As previously stated, mortality rates for suburban deer populations are usually low. Eliminating reproduction within the deer herd will not reduce total deer numbers for several years after initiating the antifertility program.
4. **Timing of Drug Administration**
   Abortion agents, such as Prostaglandin $F_{2\alpha}$, must be administered at a certain period of fetal development in order to effectively control reproduction. Females treated during early gestation are often not affected by the drug. If the drug is effective, females often resume their normal estrous cycles after abortion. When treated during late gestation, abortion-related animal behavior may repulse humans (abortion of late-term fetuses and fetal cannibalism; Waddell et al. 2001).

7. PREDATOR REINTRODUCTION

Stakeholders often suggest predator reintroduction as a means of controlling deer overabundance with minimal human involvement. Coyotes (*Canis latrans*), bobcats (*Lynx rufus*), and black bears

(*Ursus americanus*) are currently the principle white-tailed deer predators within most of the eastern United States. While these predators are undoubtedly important sources of annual fawn mortality, research has shown that this predation is not sufficient to reduce high population densities. Historic predators such as wolves (*Canis sp*.) and mountain lions (*Puma concolor*) are known to control population densities of large ungulates. However, restoration of these predators within suburban areas is not feasible because of unsuitable habitat and human safety concerns.

8. ADJACENT PROPERTIES

The legal harvest of deer on neighboring properties may help control deer populations. Harvests on these neighboring properties should be encouraged, as long as these measures can be implemented safely.

9. LOCAL OPTIONS

Local options are techniques that can be utilized to prevent deer from damaging small areas (yards, gardens, etc.). These techniques include fencing, repellants, the use of dogs, etc.

Feeding

Even though many people enjoy providing food for deer and other wildlife, feeding encourages large congregations of deer to inhabit small areas. Feeding exacerbates an already problematic situation by restricting deer movements and enhancing their reproduction and survival. This practice also makes them more tame and fearless of people.

Community education efforts regarding the negative impacts of feeding may help alleviate this problem. Alternately, regulations which prohibit feeding have been passed in some areas with varying degrees of success. For example, Elkins Lake subdivision in Walker County, Texas successfully passed an anti-feeding regulation in 2004. Large deer congregations, which were previously observed traveling from one feeding area to another, were significantly reduced. However, total elimination of supplemental feeding has not occurred within this area. It is important to note that enforcement of these regulations can be difficult without substantial community interest and involvement (DeNicola et al. 2000).

Fencing

Deer can sometimes be excluded from small areas with a variety of fence designs. Texas Parks and Wildlife Department can provide more information regarding these fencing projects.

Use of Unpalatable Plants

While deer have a definite preference for some plants over others, very few plants can be considered "unpalatable", meaning that deer will always avoid them. Furthermore, certain plants can be more or less palatable depending on deer densities and overall forage availability, time of year, and individual plant health (which can be changed with supplemental water and fertilizer). However, utilizing plants known to be less desirable to deer may help to alleviate unwanted damage to suburban landscaping. Texas Parks and Wildlife Department can provide more information regarding regional plant species that are less preferred by deer.

Repellants

Numerous commercial deer repellants have been developed to prevent unwanted damage to commercial crops, residential gardens, and landscape plants. Refer to DeNicola et al. (2000) or Coey and Mayer (2004) for a comprehensive listing of available commercial repellants. Unfortunately, the success of these substances in preventing deer damage has been limited. The ability to deter deer browsing pressure on any particular plant by applying a repellant is dependant on deer densities and overall forage availability, plant species, and the amount of time passed since repellant application. Most successful attempts to deter deer with repellants typically occur with relatively low deer densities and frequently repeated repellant applications. It is important to note that total avoidance of repellants by deer is rare (DeNicola et al. 2000).

Non-commercial treatments with items such as human hair or soap are not reliable deer repellants.

Types of Commercial Repellants (Beauchamp 1997; Mason 1997; Wagner and Nolte 2001):

- **Fear** (odor-based substances that imitate predator scents; e.g., Deer-Away®, Hinder®, Deer Buster's™, etc.)
- **Conditioned aversion** (causes illness that deer associate with treated item; e.g., Detour™, etc.)
- **Pain** (causes pain or irritation to mucous membranes; e.g., Hot Sauce®, Deer-Away®, etc.)
- **Taste** (include bittering agents in attempt to negatively affect taste; e.g., Ropel®, Tree Guard®, Orange TKO, etc.)

* Not all deer repellants are approved for application on edible crops. Inspect labels carefully.

Harassment Techniques

Noise-makers, motion-activated lights, silhouettes, and movement contraptions are often utilized in an attempt to repel deer. These techniques are mostly ineffective. Deer are extremely adaptable, and become habituated to these sights and sounds in a very short period of time. Furthermore, some of these harassment techniques will have limited application within subdivisions where loud noises are prohibited.

In some situations, dogs contained by a leash or an invisible fencing system have been used to successfully deter deer from small acreages. It is important to remember that only the area within the dog's reach will be protected, however, as deer quickly learn the dog's boundaries. Dogs must patrol the area night and day in order for this technique to be successful. Additionally, the dog's size and temperament will affect this technique's success.

REFERENCES

Beauchamp, G. K. 1997. Chemical signals and repellency: problems and prognosis. Pages 1-10 *In* J. R. Mason, editor. Repellents in wildlife management: proceedings of the symposium, 8-10 August 1995, Denver, Colorado. National Wildlife Research Center, Fort Collins, Colorado, USA.

Beringer, J., L. P. Hansen, W. Wildling, J. Fischer, and S. L. Sheriff. 1996. Factors affecting capture myopathy in white-tailed deer. Journal of Wildlife Management 60:373-380.

Butfiloski, J. W., D. I. Hall, D. M. Hoffman, and D. L. Forster. 1997. White-tailed deer management in a coastal Georgia residential community. Wildlife Society Bulletin 25:491-495.

Conover, M. 2002. Resolving human-wildlife conflicts: the science of wildlife damage management. CRC Press, LLC, Boca Raton, Florida. 418p.

Coey, B. and K. Mayer. 2004. A Gardener's Guide to Preventing Deer Damage. California Department of Fish and Game, Wildlife Management Division, Deer Program. 24p.

DeNicola, A. J., S. J. Weber, C. A. Bridges, and J. L. Stokes. 1997. Nontraditional techniques for management of overabundant deer populations. Wildlife Society Bulletin 25:496-499.

DeNicola, A. J., K. C. VerCauteren, P. D. Curtis, and S. E. Hygnstrom. 2000. Managing white-tailed deer in suburban environments – a technical guide. Cornell Cooperative Extension. 56pp.

Doerr, M. L., J. B. McAninch, and E. P. Wiggers. 2001. Comparison of 4 methods to reduce white-tailed deer abundance in an urban community. Wildlife Society Bulletin 29:1105-1113.

Frost, H. C., G. L. Storm, M. J. Batcheller, and M. J. Lovallo. 1997. White-tailed deer management at Gettysburg National Military Park and Eisenhower National Historic Site. Wildlife Society Bulletin 25:462-469.

Jones, J. J. and J. H. Witham. 1990. Post-translocation survival and movements of metropolitan white-tailed deer. Wildlife Society Bulletin 18:434-441.

Jordan, P. A., R. A. Moen, E. J. DeGayner, and W. C. Pitt. 1995. Trap-and-shoot and sharpshooting methods for control of urban deer: the case history of North Oaks, Minnesota. *In* J. B. McAninch, ed., Urban deer: a manageable resource? Proceedings of a Symposium at the 55th Midwest Fish and Wildlife Conference, The Wildlife Society.

Kilpatrick, H. J. and K. K. Lima. 1999. Effects of archery hunting on movement and activity of female white-tailed deer in an urban landscape. Wildlife Society Bulletin 17:433-440.

Kilpatrick, H. J. and W. D. Walter. 1999. A controlled archery deer hunt in a residential community: cost, effectiveness, and deer recovery rates. Wildlife Society Bulletin 27:115-123.

Kilpatrick, H. J., A. M. LaBonte, and J. A. Seymour. 2002. A shotgun-archery deer hunt in a residential community: evaluation of hunt strategies and effectiveness. Wildlife Society Bulletin 30:478-486.

Lund, R. C. 1997. A cooperative, community-based approach for the management of suburban deer populations. Wildlife Society Bulletin 25:488-490.

Mason, J. R. 1997. Vertebrate repellents: mechanisms, practical applications, possibilities. Pages 11-16 *In* K. K. Wagner and D. L. Nolte, editors. Wildlife Damage Management for Natural Resource Managers. United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, Olympia Field Station, Olympia, Washington, USA.

New Hampshire Fish and Game Department. 1996. An evaluation of deer management options. Publication No. DR-11. 16p.

O'Bryan, M. K. and D. R. McCullough. 1985. Survival of black-tailed deer following relocation in California. Journal of Wildlife Management 49:115-119.

Rudolph, B. A., W. F. Porter, and H. B. Underwood. 2000. Evaluating immunocontraception for managing suburban white-tailed deer in Irondequoit, New York. Journal of Wildlife Management 64:463-473.

Sage, R. W., Jr., W. C. Tierson, G. F. Mattfield, and D. F. Behrend. 1983. White-tailed deer visibility and behavior along forest roads. Journal of Wildlife Management 47:940-953.

Stout, R. J., B. A. Knuth, and P. D. Curtis. 1997. Preferences of suburban landowners for deer management techniques: a step towards better communication. Wildlife Society Bulletin 25:348-359.

Stradtmann, M. L., J. B. McAninch, E. P. Wiggers, and J. M. Parker. 1995. Police sharpshooting as a method to reduce urban deer populations. *In* J. B. McAninch, ed., Urban deer: a manageable resource? Proceedings of a Symposium at the 55th Midwest Fish and Wildlife Conference, The Wildlife Society.

Ver Steeg, J. M., J. H. Witham, and T. J. Beissel. 1995. Use of bowhunting to control deer in a suburban park in Illinois. *In* J. B. McAninch, ed., Urban deer: a manageable resource? Proceedings of a Symposium at the 55th Midwest Fish and Wildlife Conference, The Wildlife Society.

Waddell, R. B., D. A. Osborn, R. J. Warren, J. C. Griffin, and D. J. Kesler. 2001. Prostaglandin $F_{2\alpha}$–mediated fertility control in captive white-tailed deer. Wildlife Society Bulletin 29:1067-1074.

Wagner, K. K. and D. L. Nolte. 2001. Comparison of active ingredients and delivery systems in deer repellents. Wildlife Society Bulletin 29:322-330.

TEXAS
PARKS &
WILDLIFE

4200 Smith School Road
Austin, TX 78744

PWD BK W7000-1197

<u>Great Trinity Forest Management Plan</u>

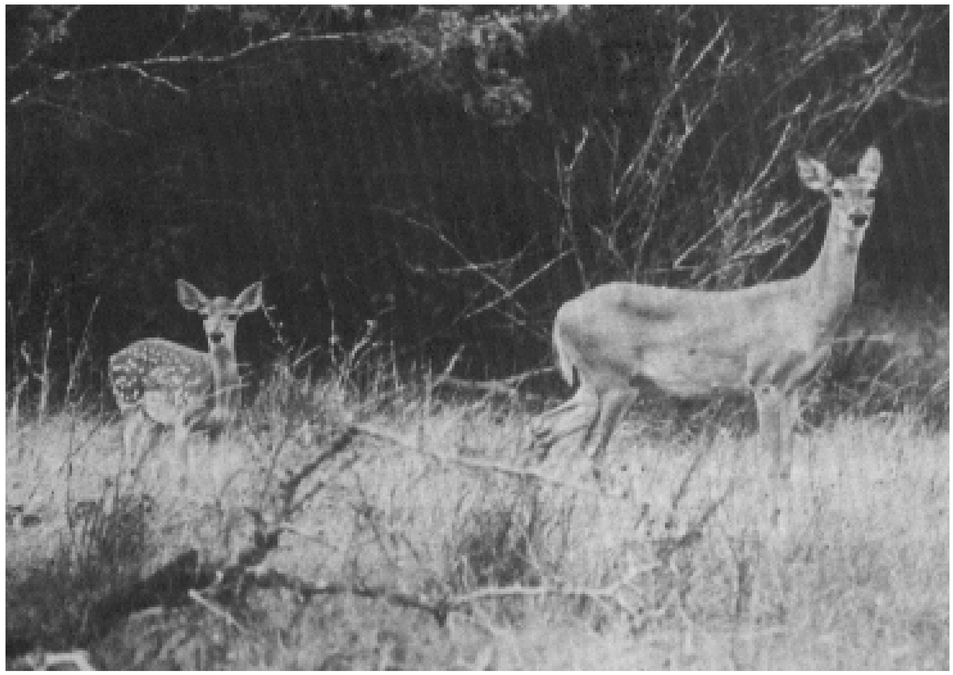
Wildlife Management

Deer Census Techniques

Deer Census Techniques

by Milo J. Shult, Wildlife Specialist, Texas Agricultural Extension Service and
Bill Armstrong, Wildlife Biologist, Texas Parks and Wildlife

Why Count Deer?



The white-tailed deer is the No. 1 big game animal in Texas. In fact, Texas has more whitetails than any other state. We harvest more deer annually than most states have in their entire herds. This resource provides tremendous hunting recreation for Texans as well as over 16 million pounds of boneless venison each year.

The great bulk of these animals live on privately owned farms and ranches. Our state is composed of over 95 percent privately owned lands. The harvestable surpluses of deer and other game animals provide landowners with opportunities for increased agricultural income through hunting leases. Continued high quality hunting recreation and increased ranch income are dependent on how well deer herds are managed.

Good deer management doesn't "just happen." It requires a basic understanding of how deer live and how they fit into the range management programs on ranches devoted to livestock-wildlife production. The nutritional requirements must be understood and applied to the vegetative types that exist on the range. For this reason, the number of deer present must be accurately estimated so that populations can be balanced with food supply and livestock which compete for the food supply.

Certainly the ideal situation would be to have a complete count or census of all deer on a particular ranch or in a particular pasture. Unfortunately, complete counts of deer are nearly impossible to obtain, even where animals are confined under a high fence. Unlike domestic livestock which can be rounded up and counted, deer do not confine their activities to large herd groups and cannot be rounded up successfully. For this reason, <u>sample census</u> methods must be used.

Wildlife biologists have had to rely on various sample census techniques to estimate wild populations. The basic principle involved is that if wildlife numbers can be estimated on a known area which is representative of a larger area, those estimates can be applied to the larger area. The key is to sample the study area as well as possible and make sure it is representative of the habitat type the estimates will be used on. For example, if a sample is taken only in heavy juniper stands, the population estimates could not be well used in an open oak savannah.

It must be recognized that censuses are estimates and, therefore, subject to some error. Wildlife managers have done a good job if their estimate is within plus or minus 10 percent of the actual population.

Since deer are living creatures capable of responding to slightly decreased numbers with increased survival of young, these errors are quite tolerable for management purposes and to dictate harvest levels. In fact, where population estimates are carefully made each year under as nearly the same conditions as possible, the trends are as important, if not more important, than the actual numbers in any one year.

In some parts of the country, "sign" can be used to estimate deer herd densities. For example, where mule deer migrate from summer to winter ranges, track counts can be used along migration routes. Or, where deer are the main large herbivores, the condition of major food plants gives an indicator of use and, therefore, population density. When highly palatable plants are being heavily used as well as some plants of secondary importance, deer numbers should be reduced to prevent range depletion. In our area, however, the most widely used census techniques are "strip census" ones which entail counting deer over a known route and estimating the acreage observed.

Before discussing these techniques in detail, however, it is important to remember that herd composition is as important as total numbers. Buck:doe ratios tell us how much of the harvest should be composed of females and how much of males. Some ranchers, biologists, and hunters believe an ideal situation would be a 1:1 ratio as this reflects the approximate way the animals are replaced by births; however, to maintain a deer population at this ratio requires intensive management. In practice a ratio of 1 buck to 2 does is not bad. As these ratios get higher, however, the number of harvestable bucks is decreased. In a herd at carrying capacity, a 1:10 buck:doe ratio tells us we have too many females and fewer bucks to harvest. If meat production was the only goal, this would not necessarily be bad. However, the consumer (hunter) is primarily interested in harvesting bucks. Thus, the rule of thumb is to harvest bucks and does based on the ratios that the census indicate.

Another important ratio which we can get from a census is that of fawns per doe. This gives us an indication of herd health since reproduction will be low when females are stressed as by poor nutrition on depleted ranges. In good deer habitat, adult females tend to have twins with triplets not being uncommon. In marginal to poor habitat, singles become the rule and fawn survival is decreased. The number of fawns produced and their survival is important to future hunting seasons.

Deer Census Methods

Three types of census that can be used by private landowners to census deer on their property are the Hahn, Spotlight, and Mobile Line techniques. All are designed to be used just prior to hunting seasons (usually October) and do not require the use of special equipment.

These three methods determine deer populations by observing animals on a calculated number of acres. In other words, a census line is established by determining the number of acres which can be seen along a given route. Dividing the number of acres by the number of deer seen gives an estimate of the population expressed as acres per deer. This number, when based on a representative sample can be expanded to estimate the number of deer on a given ranch.

To determine the number of acres observed along the route the distances which deer can be seen to the right and left of the line are measured at regular intervals. When these distances are totaled and divided by the number of stops, an average width of the census strip is calculated. The average width (usually in yards) is then multiplied by the length of the line (in yards). This will give square yards in the sample and square yards divided by 4,840 (sq. yds. per acre) will give acres seen.

The visibility can also be determined from an aerial photo, although most people prefer ground estimates.

One general rule to follow in measuring acreage is that distances are not measured across an open draw or gully and deer are not counted across the draw or gully. Also, distances are not to exceed 250 yds. to the right or left of the line and deer are not counted past these distances. All lines should be well marked to insure the same route is followed in future years. This is normally not a problem with

Example:

A line two miles long is walked and, based on the visibility to the right and left at 100 yd. intervals, the average width is 150 yds.

2 miles x 1,760 yds/mile = 3,520 yds. strip length

3,520 yds. (strip length) x 150 yds. (average width) = 528,000 sq. yds. observed

528,000 sq. yds. ÷ 4,840 sq. yds./acre = 109 acres observed

If 11 deer were observed, the density would be 109 acres ÷ 11 deer = 9.9 acres per deer.

driving lines on roads but walking (Hahn) lines should be clearly marked with fence posts, trees, or piles of rocks spot-painted with brightly colored paint.

Hahn Line

A Hahn line (named for Henry Hahn who devised the technique) is a strip census in which numbers of deer are counted along a 2-mile strip by one man walking. The general directions for establishing and using a Hahn line are as follows:

1. The line should be laid out on an east-west axis and always walked from west to east in the evening (sun at observer's back). It may be 1-3 miles long with 2 miles being optimum.

2. Visibility should be taken at 100 yard intervals along the line. In establishing the line, two men are used. One stays on the line and the other walks out at right angles. When the walker disappears from view in the brush, the line man signals him to stop and the distance walked is the visibility.

3. One line per 1,000 acres should be established if possible.

4. The line should be walked at least twice and the results averaged. The more times it is walked the more precise the count will be.

5. The line should be walked in late September or October. Start the line 30 minutes prior to official sunset for a 2-mile line.

6. All deer observed should be recorded. When possible they should be identified as bucks, does, or fawns.

7. The weather conditions are important. Ideal weather would be a southerly wind less than 15 mph, a cloud of less than 50%, and a relative humidity of less than 70%.

8. The Hahn method is accurate on ranges with high deer densities like the Edwards Plateau. The reliability decreases with low deer populations.

Spotlight Census

The spotlight technique involves counting deer at night using a vehicle (preferably a pickup). One person drives the vehicle and preferably two people count deer and make visibility estimates from the bed of the truck. Aircraft or high intensity spotlights are used. This is considered the most consistent method of deer census. However, while it provides a valuable density data and is easy to do, it does not work as well for composition (buck:doe, doe:fawn) data. For this reason, a daylight mobile line may be run to assist in obtaining this information. The criteria for a spotlight line are as follows:

1. The count should be started 45 minutes to 1 hour after official sunset.

2. The driver should not exceed 10 mph. On ranch roads 5-7 mph is preferable.

3. Texas Parks and Wildlife uses lines at least 15 miles long. Shorter lines may be used on a ranch but should be run frequently.

4. Visibility is taken at 1/10 mile intervals along the route.

5. Winds should be less than 20 mph and cloud cover less than 50%. Relative humidity should be less than 70%.

6. Record all deer observed within the sample area. Identify as to sex and age when possible.

7. The local game warden should always be contacted prior to the

count and advised of spotlighting activities, time of spotlighting, and exact location of the activity. No weapons should be carried in the vehicle.

Mobile Line

This technique involves one person driving a vehicle over a marked route to count deer on a measured acreage. It can also be used to count deer without estimating acreage for buck:doe and doe:fawn ratios. It is the least accurate of the three techniques for density figures. The criteria are as follows:

1. The line should run west to east and be approximately 7 miles long if possible.

2. The census should be started 30 minutes before official sundown for a 7-mile line.

3. Weather conditions should be southerly wind less than 15 mph, cloud cover less than 50% and relative humidity less than 70%.

4. Visibility should be taken to the right and left at 2/10 mile intervals if a density estimate is desired.

Other Information

Certain other observations can be made which will increase the reliability of census methods. Some of these are:

1. **Casual Observations:** Keep records of all deer seen from August until the opening of hunting season. Use binoculars to class deer as bucks, does, fawns, and undetermined. This will help verify buck:doe and doe:fawn ratios.

2. **Watch Vegetation:** Deer feed primarily on forbs (broad-leafed plants sometimes classed as weeds) and browse. Watch these indicator plants to determine too heavy deer use or heavy competition from livestock.

3. **Harvest Records:** Quality of deer in the harvest can say a lot about what is happening in a deer herd. Recording antler size, body weights, and body condition are all important. However, they must be related to age. Each deer should be aged to see if it is a young deer doing well or an older deer doing poorly. Texas Parks and Wildlife or your County Extension Agent can provide you with materials to learn about how to age deer. These records from harvested animals will be useful in years to come to evaluate the progress of your management program.

Remember, all census information is trend data. Annual records should be retained to compare population trends and to assist in determining the impact of management practices.

4200 Smith School Rd
Austin, Texas 78744
1-800-792-1112
www.tpwd.state.tx.us

PWD BK W7000-083 (10/99)
In accordance with Texas Depository Law, this publication is available at the Texas State Publications Clearinghouse and/or Texas Depository Libraries.

Great Trinity Forest Management Plan

Wildlife Management

Herd Composition: An Essential Element of White-tailed Deer Population and Harvest Management in the Cross-Timbers of North Texas

HERD COMPOSITION: AN ESSENTIAL ELEMENT OF WHITE-TAILED DEER POPULATION AND HARVEST MANAGEMENT IN THE CROSS-TIMBERS OF NORTH TEXAS

Jim Dillard, Technical Guidance Biologist, Mineral Wells

INTRODUCTION

White-tailed deer management consist of a series of strategies, practices, and other actions taken on the part of landowners and land managers to produce and sustain populations of this important game animal. **Habitat management**, **population management**, and **harvest management** are all essential ingredients for accomplishing a successful white-tailed deer management program. It is the degree of importance that landowners or wildlife managers place on these different stages of management that will determine long term results. Knowledge of the composition of a deer herd is fundamental to making sound management decisions.

HERD COMPOSITION - WHAT IS IT?

Herd composition refers to the **ratio of bucks, does, and fawns in the population.** In addition, the ratio of <u>does to bucks</u> and <u>fawns to does</u> are also key population relationships used to implement and evaluate management and harvest strategies. An estimate of the **percent bucks, does, and fawns** in the total population must be known before harvest rates can be accurately formulated.

Deer are born at approximately a one-to-one sex ratio; however, few free ranging populations reflect this ratio. Herd composition is not static but changes throughout the year due to the cumulative influences of hunting pressure, reproduction, natural mortality (diseases, accidents, predation, etc.), range conditions and land use, and environmental factors such as rainfall patterns, temperatures, drought, or floods.

Although the exact number of deer living on most ranches is impossible to determine, various techniques are available that estimate their numbers. Techniques such as spotlight surveys, walking Hahn transects, mobile daytime census, and aerial counts are common methods used to estimate the relative density of deer. With each of these techniques, deer are counted on a given area of space or acreage. The number of deer observed divided by the number of acres sampled is expressed as **<u>acres per deer.</u>** An estimate of the total population can then be determined by expanding this figure to the total ranch acreage. For example, a 5,000-acre ranch with an estimated density of 25 acres per deer has an estimated total deer population of 200 deer. Unless a significant number of observed deer are identified as to sex and age class, estimated herd composition will be unknown. In most situations, not enough deer are identified while conducting these types of surveys, which must be supplemented by additional **herd composition counts.**

WHEN DO YOU CONDUCT HERD COMPOSITION COUNTS?

Deer herd composition counts should be made during that time of the year when bucks, does, and fawns are most easily identifiable. The exact time of the year may vary across the state due to differences in fawning dates and antler formation on bucks. Counts initiated before peak fawning has occurred or prior to advanced antler formation will not provide data reflective of the population sex or age composition. Also, fawns are not actively up and moving with does until they are 6-8 weeks of age. It is recommended that herd composition counts in the Cross-Timbers be conducted during August and September.

The differential size between fawns and adult deer is most evident during this period. The spotted hair coat on fawns begins to disappear during late September in the Cross-Timbers when molt occurs, making identification uncertain unless a mature size deer is nearby. Fawns begin to grow rapidly by this time, making positive identification difficult. Early fawns may be misidentified as yearlings on counts made after this time. Antler development on bucks has also progressed during this period making them readily identifiable.

Herd composition counts should be completed by the end of September to allow time for harvest rates to be calculated and preparations made for the upcoming archery and general gun seasons.

HOW DO YOU MAKE HERD COMPOSITION COUNTS?

Herd compositions counts can be made any time of the day or night. Since deer are most active during the early **morning and late evening**, efforts to observe deer during these periods are most productive. Identification of deer during daylight hours is also easier than night observations with spotlights and a higher percentage of deer can be accurately identified by sex and age. Most counts can be made from a slow moving vehicle along ranch roads. Counts can be made at random, along a systematic route, or at specific locations where deer are feeding or congregating. Grain fields, food plots, water sources, natural crossings, or tree lines are good places to observe deer. Counts may also be made from hunting blinds or other stationary structures where deer are known to occur. **The use of binoculars or spotting scopes is a must!**

Record **only** deer that can be identified as a buck, a doe, or a fawn. When a group of deer is observed, **do not** record **any** of the deer unless **all individuals** can be positively identified. If you see a deer but can not identify it - don't record it. Do not assume the identity of deer or counts will become biased. Fawns and mature bucks are usually easy to identify. Yearling bucks or spikes are often mistaken as does. Every effort must be made to be sure you properly identify all deer. Avoid recording the same individual deer on different dates if possible. Your objective is to observe a representative cross section of deer throughout the total population on your ranch.

Remember that many deer during this time of the year are in small family groups, which may consist of a doe with this year's fawn or fawns, and her doe or buck yearling from the previous year. Other groups may consist of several does and their collective fawns. And, during August, bucks are often observed in groups away from the does. As September progresses, bucks become less tolerant of each other and are often observed as singles.

Take your time when you see a deer. There may be other deer standing nearby that you won't see unless the group begins to move or run. Fawns may be hidden in tall grass and not seen until the doe begins to move away. Be patient!

Data should be recorded on a simple form that has columns for the date, bucks, does, fawns, and total. When all herd composition observations are completed, simply add the total number of bucks, does, and fawns observed together. It is recommended that a minimum of **100** individual deer be identified if possible. **The more the better!**

HOW DO YOU DETERMINE HERD COMPOSITION FROM THE DATA?

From your data sheet, **total** the columns for **bucks, does, and fawns** and **add them together**. This figure represents **total deer identified**. To determine estimated herd composition, **divide** each individual group (bucks, does, and fawns) by the **total number of identified deer** then multiply that number by 100 to get the percentage. For example, if a total of 100 deer were identified and 20 were bucks, 50 were does, and 30 were fawns, calculate herd composition as follows:

20 (# of identified Bucks) divided by 100 (total identified Deer) = .20 x 100 = **20% Bucks**
50 (# of identified Does) divided by 100 (total identified Deer) = .50 x 100 = **50% Does**
30 (# of identified Fawns) divided by 100 (total identified Deer) = .30 *x* 100 = **30% Fawns**
100 Total Identified Deer 100%

In addition, **doe to buck** and **fawn to doe** ratios can also be determined. To determine the **doe to buck ratio**, **divide the number of identified does** by **the number of identified bucks**. To determine the **fawn to doe ratio, divide the number of identified fawns** by **the number of identified does:** For example:

Divide 50 (# identified Does) *by* 20 (# identified Bucks) = **2.50 Does per Buck**
Divide 30 (# identified Fawns) *by* 50 (# identified Does) = **0.60 Fawns per Doe**

HOW DO YOU USE HERD COMPOSITION DATA?

Once you have estimated what your deer herd composition is and expressed it as **percent bucks, does, and fawns,** you may now apply these figures to your total estimated deer population. For example, a ranch containing 2,000 acres with an estimated deer density of one deer per 20 acres has an estimated population of 100 deer. Calculate herd composition as follows:

100 Total Deer ***X*** .20 percent (% identified Bucks) = **20 Bucks**
100 Total Deer ***X*** .50 percent (% identified Does) = **50 Does**
100 Total Deer ***X*** .30 percent (% identified Fawns) = **30 Fawns**
100 Total Deer

With the knowledge of approximately how many bucks, does, and fawns are present on your ranch, you may now made important decisions about how many deer should be harvested during the upcoming deer season. Buck to doe ratios and fawns to doe ratio also are good indicators of your progress toward obtaining your goals and objectives.

Great Trinity Forest Management Plan

Wildlife Management

White-Tailed Deer Browse Preferences in a Southern Bottomland Hardwood Forest

White-Tailed Deer Browse Preferences in a Southern Bottomland Hardwood Forest

Steven B. Castleberry, *D.B. Warnell School of Forest Resources, University of Georgia, Athens, GA 30602;* **W. Mark Ford,** *Westvaco, Timberlands Division, Rupert, WV 25984;* **Karl V. Miller,** *D.B. Warnell School of Forest Resources, University of Georgia, Athens, GA 30602; and* **Winston P. Smith,** *USDA Forest Service, Pacific Northwest Research Station, Juneau, AK 99801*

ABSTRACT: *We examined spring and summer use of woody browse by white-tailed deer* (Odocoileus virginianus) *in forest gaps created by group selection timber harvest in a South Carolina bottomland hardwood forest during 1995 and 1996. Percent available twigs browsed, relative abundance, and relative use were calculated for each species with more than 50 twigs sampled. We used chi-square analysis to rate species as preferred, proportional, or low use. Total percent browsed was low in both years (2.5% in 1995; 3.0% in 1996). In 1995, 6 species were rated as high use, 4 species as proportional use, and 10 species as low use. In 1996, 6 species were rated as high use, 7 as proportional use, and 9 as low use. Species ratings generally were in agreement with other food habits studies in the Southeast. Preferred browse species included red maple* (Acer rubrum), *winged elm* (Ulmus alata), *greenbrier* (Smilax *spp.), and black willow* (Salix nigra). *The low rates of browsing probably were due to low use of the study area by deer during the growing season. Deer browsing likely had little impact on regeneration of most species in this bottomland hardwood forest. South. J. Appl. For. 23(2):78–82.*

The food habits of white-tailed deer have been studied in all physiographic provinces and in a variety of habitat types in the southeastern United States. (Harlow and Hooper 1972, Murphy and Noble 1973, Warren and Hurst 1981, Johnson et al. 1995). Yet few researchers have examined use and availability of woody browse species in southern bottomland hardwood forests. Furthermore, the relationship between deer browsing preference and the potential impacts on bottomland hardwood regeneration is poorly understood.

Sheffield (1957) and Murphy and Noble (1973) examined deer forage use and availability in bottomland forests in Louisiana and found that the annual diet consists primarily of blackberries (*Rubus* spp.), asters (*Aster* spp.), and woody vines, while woody seedlings and forbs make up a smaller percentage of the total diet. Deer food habits have been examined in bottomland forests of the Atlantic Coastal Plain, but browse use in relation to availability is not well documented. Harlow et al. (1979) used rumen content analysis to compare seasonal diets of deer from swamp and upland habitats on the Savannah River Site (SRS), South Carolina, but rumen content analysis alone does not yield information about forage use relative to availability. Moore (1967) examined browse availability and utilization on the SRS but only during winter when deer typically do not utilize woody twigs in the Southeast (Cushwa et al. 1970, Harlow and Hooper 1972, Johnson et al. 1995).

Southern bottomland hardwood forests are valued for timber production, floodwater storage, enhanced water quality, nutrient cycling, erosion control, and wildlife habitat (Kellison and Young 1997). Because deer herbivory can adversely impact regeneration of commercial species and cause changes in species composition in other habitat types (Hough 1965, Ross et al. 1970, Anderson and Loucks 1979, Marquis 1981, Tilghman 1989), an understanding of the impacts in southern bottomland hardwood forests is needed if the ecological functions, attributes, and dynamics of these areas are to be maintained. We examined spring and summer availability and utilization of woody browse species within various-sized group selection cuts in a southern bottomland hardwood forest to assess browsing preference and the potential impacts of deer herbivory on regeneration of commercial tree species.

NOTE: Karl V. Miller is the corresponding author and can be reached at (706) 542-1305; Fax: (706) 542-8356; E-mail: kmiller@smokey.forestry.uga.edu. Primary funding for this study was provided by the U.S. Department of Agriculture (CSRS) Competitive Grant No. 93-37101-8662. Additional support was provided by the USDA Forest Service Center for Bottomland Hardwoods Research, U.S. Department of Energy Savannah River Biodiversity Program, the University of Georgia Daniel B. Warnell School of Forest Resources, and McIntire-Stennis Project No. GEO-0074-MS. We thank the personnel at the Savannah River Forest Station, particularly Dr. John Blake, for assistance throughout the study. We also thank those who provided field assistance. Manuscript received September 4, 1997, accepted May 26, 1998.

Study Area and Methods

The study was conducted on the Savannah River Site (SRS) in west-central South Carolina in the Upper Coastal Plain physiographic province. The study area was a 120 ha, 70-yr-old, bottomland hardwood stand located 1.5 km east of the Savannah River. Common tree species on the study area were swamp chestnut oak (*Quercus michauxii*), laurel oak (*Q. laurifolia*), cherrybark oak (*Q. falcata* var. *pagodaefolia*), loblolly pine (*Pinus taeda*), and sweetgum (*Liquidambar styraciflua*) at a basal area of 33 m^2/ha (Pauley et al. 1996). The Society of American Foresters classification was Type 91, swamp chestnut oak-cherrybark oak (Shropshire 1980).

Surrounding upland areas on the SRS are predominantly forested. Following acquisition by the Department of Energy in 1950, upland agricultural areas were planted to pine, predominately loblolly and longleaf (*P. palustris*). Currently, pine stands are managed on a sawtimber rotation with approximately 12% of the upland pine type currently classified as regeneration areas. Upland hardwood stands are small and constitute less than 3% of the upland area. Seven percent of the uplands is classified as nonforested, which includes industrial facilities, rights-of-way, and water.

We used group selection cuts to create 36 openings (gaps) in the forest canopy in December 1994. The 36 gaps ranged in sizes from 0.02 to 0.50 ha. Trees were felled with mechanized harvesting equipment and grapple skidded to loading decks. Culls and undersized stems were manually felled before the first growing season, but no site preparation was performed.

We randomly established 24 vegetation sample plots (0.5 m^2) in each exclosure type gap and sampled 4 each month between April and September of 1995 and 1996. We recorded the number and species of browsable woody twigs and the number of twigs browsed by deer. Browsable twigs are defined as twigs more than 1 cm in length and occurring within 1.25 m of the ground. Identification and taxonomy followed Radford et al. (1968).

No browsing by other mammalian herbivores was identified, so all browsing (excluding insects) was considered to be caused by deer. We summed data across all gaps and used chi-square analysis to categorize species as high, proportional, or low use, based on whether the proportion of twigs browsed for that species was greater ($P < 0.05$), not different ($P > 0.05$), or less ($P < 0.05$) than the proportion of twigs of all species browsed (Strole and Anderson 1992). Because of low overall browsing rates, only species with more than 50 twigs sampled were included in the analysis. Three descriptive statistics were calculated for each species: Percent Available Twigs Browsed (PATB) = (total number of twigs of a species browsed/total number of twigs of a species) × 100; Relative Abundance (RA) = (total number of twigs of a species/total number of twigs of all species) × 100; and Relative Use (RU) = (total number of twigs of a species browsed/total number of twigs of all species browsed) × 100.

We used fecal pellet group counts (Bennett et al. 1940) to index use of the bottomland habitat by deer. Counts were conducted four times per year (spring, summer, fall, and winter) in 1995 and 1996 by walking established transect lines and removing all pellet groups within 2 m on each side of the line. The lines were walked again approximately 7 days later, and the number of pellet groups encountered was recorded. In 1996, a sample of pellet groups was marked with stand-up flags to examine the effect of dung beetles on persistence. The marked groups were examined after 7 days and the condition of each was noted.

Results

In 1995, 20 species were included in the analysis (Table 1). A total of 12,460 twigs was recorded, and 306 of those were browsed (2.5%). Six species, including red maple, rattan vine (*Berchemia scandens*), hackberry (*Celtis laevigata*), greenbrier, winged elm, and blueberries (*Vaccinium* spp.), were classified as high-use species. Trumpet creeper (*Campsis radicans*), blackgum (*Nyssa sylvatica*), American sycamore (*Platanus occidentalis*), and overcup oak (*Q. lyrata*) were classified as proportional-use species. The remaining ten species were classified as low use. Relative abundance values ranged from 0.5 to 18.2, whereas relative use values ranged from 0 to 34.6.

In 1996, 22 species were included in the analysis (Table 2). A total of 21,163 twigs was recorded, and 638 of those were browsed (3.0%). Red maple, trumpet creeper, red oaks (*Quercus* spp.), black willow, greenbrier, and winged elm were classified as high-use species. Seven species were classified as proportional-use species. These included red buckeye (*Aesculus pavia*), rattan vine, hackberry, blackgum, cherrybark oak, winged sumac (*Rhus copallina*), and blackberries (*Rubus* spp.). The remaining nine species were classified as low use. Relative abundance values ranged from 0.2 to 17.2 whereas relative use values ranged from 0 to 32.4.

Fecal pellet group counts indicated strong seasonal changes in habitat use on the study area (Table 3). Use of the study area was very low during spring and summer and increased during fall and winter. This pattern of habitat use was consistent during both years of the study. All pellet groups marked during 1996 counts were still visible after 7 days, so dung beetles apparently did not affect persistence during the period between clearing and counting.

Discussion

The low browsing rates we observed likely were a result of low use of the study area by deer during the growing season. Pellet group counts indicated that deer used the study area almost exclusively during fall and winter when oak mast was available. Although deer were present on the study area during winter, hardened woody twigs usually constitute only a small portion of deer diets during winter in the Southeast (Cushwa et al. 1970, Harlow and Hooper 1972, Johnson et al. 1995). Moore (1967) examined availability and use of browse by deer among various stand types on the SRS during winter and found little evidence of browsing, although browsing was slightly higher in bottomland stands. This same seasonal pattern of habitat use was observed in other studies in southern bottomland hardwood forests (Smith et al. 1995).

Table 1. Woody species with more than 50 twigs sampled from the Savannah River Site, South Carolina, 1995. Species are grouped as high, proportional, or low use based on results of chi-square analysis ($P < 0.05$). Values include percent available twigs browsed (PATB) including number of twigs browsed/number of twigs sampled, relative abundance (RA), and relative use (RU) for each species.

Species	PATB	RA	RU
High use			
Red maple (*Acer rubrum*)	20.8 (109/524)	4.1	34.6
Blueberries (*Vaccinium* spp.)	9.5 (19/201)	1.6	6.0
Hackberry (*Celtis laevigata*)	6.9 (12/173)	1.3	3.8
Rattan vine (*Berchemia scandens*)	6.8 (12/177)	1.4	3.8
Greenbrier (*Smilax* spp.)	5.3 (19/357)	2.8	6.0
Winged elm (*Ulmus alata*)	4.7 (94/1,989)	15.4	29.8
Proportional use			
Trumpet creeper (*Campsis radicans*)	1.5 (5/326)	2.5	1.6
American sycamore (*Platanus occidentalis*)	1.0 (1/101)	0.8	0.3
Blackgum (*Nyssa sylvatica*)	0.0 (0/76)	0.6	0
Overcup oak (*Quercus lyrata*)	0.0 (0/65)	0.5	0
Low use			
Poison ivy (*Rhus radicans*)	1.3 (24/1,825)	14.2	7.6
Blackberries (*Rubus* spp.)	0.9 (5/541)	4.2	1.6
Sweetgum (*Liquidambar styraciflua*)	0.1 (1/1,052)	8.2	0.3
Virginia creeper (*Parthenocissus quinquefolia*)	0.1 (3/2,051)	15.9	1.0
Wild grapes (*Vitis* spp.)	0.1 (2/2,344)	18.2	0.6
St. Andrew's cross (*Hypericum hypericoides*)	0.0 (0/125)	1.0	0
Loblolly pine (*Pinus taeda*)	0.0 (0/172)	1.3	0
Cherrybark oak (*Quercus falcata* var. *pagodaefolia*)	0.0 (0/131)	1.0	0
Winged sumac (*Rhus copallina*)	0.0 (0/123)	1.0	0
Dwarf palmetto (*Sabal minor*)	0.0 (0/107)	0.8	0

Table 2. Woody species with more than 50 twigs from the Savannah River Site, South Carolina, 1996. Species are grouped as high, proportional, or low use based on results of chi-square analysis ($P < 0.05$). Values include percent available twigs browsed (PATB) including number of twigs browsed/number of twigs sampled, relative abundance (RA), and relative use (RU) for each species.

Species	PATB	RA	RU
High use			
Black willow (*Salix nigra*)	39.8 (213/535)	2.5	32.4
Red maple (*Acer rubrum*)	6.7 (27/403)	1.9	4.1
Red oaks (*Quercus* spp.)	6.3 (15/237)	1.1	2.3
Trumpet creeper (*Campsis radicans*)	5.8 (26/447)	2.1	3.9
Winged elm (*Ulmus alata*)	3.5 (111/3,148)	14.5	16.9
Proportional use			
Winged sumac (*Rhus copallina*)	2.9 (19/656)	3.0	2.9
Blackberries (*Rubus* spp.)	2.7 (73/2,705)	12.5	11.1
Hackberry (*Celtis laevigata*)	2.5 (11/441)	2.0	1.7
Red buckeye (*Aesculus pavia*)	1.9 (1/52)	0.2	0.2
Blackgum (*Nyssa sylvatica*)	1.9 (1/53)	0.2	0.2
Rattan vine (*Berchemia scandens*)	1.8 (5/272)	1.3	0.8
Cherrybark oak (*Quercus falcata* var. *pagodaefolia*)	1.7 (1/60)	0.3	0.2
Low use			
Sweetgum (*Liquidambar styraciflua*)	2.2 (47/2,131)	9.8	7.2
Blueberries (*Vaccinium* spp.)	1.7 (8/478)	2.2	1.2
Poison ivy (*Rhus radicans*)	1.4 (30/2,087)	9.7	4.6
St. Andrew's cross (*Hypericum hypericoides*)	1.0 (14/1,396)	6.4	2.1
Wild grapes (*Vitis* spp.)	0.2 (9/3,736)	17.2	1.4
Virginia creeper (*Parthenocissus quinquefolia*)	0.0 (0/1,387)	6.4	0
Loblolly pine (*Pinus taeda*)	0.0 (0/377)	1.7	0
American sycamore (*Platanus occidentalis*)	0.0 (0/101)	0.5	0
Dwarf palmetto (*Sabal minor*)	0.0 (0/157)	0.7	0

Table 3. Deer density index (pellet groups/m²/day × 10^{-5}) from seasonal fecal pellet group counts at the Savannah River Site, South Carolina, 1995 and 1996.

	1995		1996	
Season	Area sampled (ha)[1]	Density index	Area sampled (ha)	Density index
Winter	4.5	24.8	3.0	17.1
Spring	6.2	0.0	6.0	1.9
Summer	6.2	0.0	4.6	0.0
Fall	6.1	3.8	5.2	8.8

[1] Area sampled varied depending on the amount of flooding on the study area.

Other factors may have contributed to the low levels of herbivory. In the Southern Appalachians, Moore and Johnson (1967) found that deer appeared to prefer sprout growth over seedlings, with preference being more closely related to succulence than to species. Regeneration during this study was largely from seedlings that germinated at the beginning of the first growing season. Without a pre-established root system, seedlings may have slower growth rates and a lower nutrient content and are not as palatable. Furthermore, the seedlings were below the height of the herbaceous growth for much of the first growing season and may not have been visible to deer. Plant apparency has been shown to influence herbivory rates (Palo et al. 1993, Van de Koppel et al. 1996). During the second growing season, seedlings were larger but still had not grown above the herbaceous layer and total percent browsed only increased 0.5%.

The species ratings may be deceiving because they were based on low total percent browsed values. For example, in 1995, total percent browsed was 2.5%, so the expected number of twigs browsed for a species would be 2.5% of the total number of twigs sampled. As a result, some species that were not browsed were rated as proportionally used because zero was not significantly different from the expected value. Because of this low overall percent browsed, a species with a relatively low PATB could be rated as high use. Winged elm, for example, was rated as high use in both years, but PATB was never above 5%. In each year, only one species that was rated high use had a PATB over 10%.

Species preference ratings generally were in agreement with other food habits studies from the Southeast. Tree species, such as red maple, winged elm, hackberry, and black willow, that were rated as high use in one or both years, often are reported as preferred browse species in the Southeast during spring and summer in other habitat types (Harlow and Hooper 1972, Sossaman and Weber 1973, Warren and Hurst 1981, Johnson et al. 1995). Red maple and black willow had higher PATB values than other species. In both species, relative use values were much higher than relative availability values, indicating that deer were preferentially selecting these species. Selective browsing by deer can affect the abundance and species composition of woody plant communities (Alverson et al. 1988). However, with the low PATB values observed, it is unlikely that deer affected regeneration of these species.

Bottomland hardwood oaks are desirable commercial species (Putnam et al. 1960), so growth and survival of oak regeneration is of special concern to forest managers Red oaks, including laurel oak, willow oak (*Q. phellos*), and water oak (*Q. nigra*), were combined for the analysis due to the difficulty of distinguishing them as seedlings. Combined, these species were rated as high use in the second year following harvest, but the PATB was relatively low. We also found little browsing on cherrybark oak by deer in this bottomland forest. While not regarded as a highly preferred browse species, cherrybark is slightly more preferred than other red oaks (Warren and Hurst 1981). We suggest that deer browsing did not have a significant impact on oak regeneration on this study area during the first 2 yr after harvest.

Most shrubs and woody vines rated as high use in this study were also found to be highly preferred in other studies (Mawk 1976, Warren and Hurst 1981, Halls and Boyd 1982). A notable exception was poison ivy (*Rhus radicans*), which was rated as low use in both years, in contrast to other studies in which it was found to be a highly preferred spring and summer browse (Murphy and Noble 1973, Warren and Hurst 1981). Blueberries were the only shrub species rated as high use in either year. All blueberry species combined for analysis were rated as high use in 1995 but low use in 1996. Due to their small size, they were not removed by the commercial harvest or the felling of the residual stems and may have been browsed to a greater degree in the first year before other species were established.

Our research suggests that herbivory may be of less concern to forest managers working in some southern bottomland systems than in other habitat types. However, the spatial arrangement of habitats surrounding this study area are not common to all southern bottomland forests and may have influenced habitat use by deer. Upland habitats, consisting of pine plantations and utility right-of-ways, surrounded the study area providing a place for deer to forage in the spring after hard mast resources were depleted. In other areas, such as the Mississippi Alluvial Valley, where bottomland habitats are more extensive, there are no nearby upland habitats. As a result, the effects of herbivory may be more significant. Therefore, it may be necessary to index deer densities prior to harvest in some locations to assess the potential impacts on regeneration.

Literature Cited

ALVERSON, W.S., D.M. WALLER, AND S.L. SOLHEIM. 1988. Forests too deer: Edge effects in northern Wisconsin. Conserv. Biol. 2:348-358.

ANDERSON, R.C., AND O.L. LOUCKS. 1979. White-tailed deer (*Odocoileus virginianus*) influence on structure and composition of *Tsuga canadensis* forests. J. Appl. Ecol. 16:855–861.

BENNETT, L.J., P.F. ENGLISH, AND R. MCCAIN. 1940. A study of deer populations by use of pellet group counts. J. Wildl. Manage. 4:370–373.

CUSHWA, C.T., R.L. DOWNING, R.F. HARLOW, AND D.F. URBSTON. 1970. The importance of woody twig ends to deer in the Southeast. USDA For. Serv. Res. Pap. SE-67. 12 p.

HALLS, L.K., AND C.E. BOYD. 1982. Influence of managed pine stands and mixed pine/hardwood stands on well being of deer. USDA For. Serv. Res. Pap. SO-183. 18 p.

HARLOW, R.F., AND R.G. HOOPER. 1972. Forages eaten by deer in the Southeast. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 25:18-46.

HARLOW, R.F., D.F. URBSTON, AND J.G. WILLIAMS, JR. 1979. Forages eaten by deer in two habitats at the Savannah River Plant. USDA For. Serv. Res. Note SE-275. 3 p.

Hough, A F 1965 A twenty-year record of understory vegetational change in a virgin Pennsylvania forest. Ecology 46:370–373.

Johnson, A.S., et al. 1995. White-tailed deer foraging in relation to successional stage, overstory type and management of Southern Appalachian forests. Am. Midland Natur. 133:18–35.

Kellison, R.C., and M.J. Young. 1997. The bottomland forest of the southern United States. For. Ecol. Manage. 90:101–115.

Marquis, D.A. 1981. Effect of deer browsing on timber production in Allegheny hardwood forests of northwestern Pennsylvania. USDA For. Serv. Res. Pap. NE-475. 10 p.

Mawk, J.D. 1976. Food habits of white-tailed deer and proximate analysis of some important deer food plants in east-central Mississippi. M.S. Thesis, Mississippi State Univ., Starkeville. 36 p.

Moore, W.H. 1967. Deer browse resources of the Atomic Energy Commission's Savannah River Project Area. USDA For. Serv. Resour. Bull. SE-6. 28 p.

Moore, W.H., and F.M. Johnson. 1967. Nature of deer browsing on hardwood seedlings and sprouts. J. Wildl. Manage. 31:351–353.

Murphy, P.K., and R.E. Noble. 1973. The monthly availability and use of browse plants by deer on a bottomland hardwood area in Tensas Parish, Louisiana. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 26:39–57.

Palo, R.T., J. Gowda, and P. Högberg. 1993. Species height and root symbiosis, two factors influencing antiherbivore defense of woody plants in East African savannah. Oecologia 93:322–326.

Pauley, E.F., B.S. Collins, and W.P. Smith. 1996. Early establishment of cherrybark oak: Effects of seed predation, herbivory and competition. P. 132–136 *in* Proceedings of the southern forested wetlands ecology and management conference, Flynn, K.M. (ed.). Consortium for Research on Southern Forested Wetlands, Clemson Univ., Clemson, SC. 332 p.

Putnam, J A , G M Furnival, and J S McKnight 1960 Management and inventory of southern hardwoods. USDA For. Serv. Agric. Handb. No. 181. 102 p.

Radford, A.E., H.E. Ahles, and C.R. Bell. 1968. Manual of the vascular flora of the Carolinas. Univ. North Carolina Press, Chapel Hill. 1,183 p.

Ross, B.A., J.R. Bray, and W.H. Marshall. 1970. Effects of long-term deer exclusion on a *Pinus resinosa* forest in north-central Minnesota. Ecology 51:1088–1093.

Sheffield, W.J., Jr. 1957. A summer deer food study in Tensas Parish, Louisiana. M.S. Thesis, Louisiana State Univ., Baton Rouge. 87 p.

Shropshire, F.W. 1980. Swamp chestnut oak-cherrybark oak, 91. P. 64 *in* Forest cover types of the United States and Canada, Eyre, E.H. (ed.). Soc. Am. For., Bethesda, MD. 148 p.

Smith W.P., R.M. Devall, and B.R. Parresol. 1995. Windthrow gaps, mammalian herbivores, and diversity of bottomland hardwood forests. USDA For. Serv., Southern Hardwoods Lab., Stoneville, MS. 123 p.

Sossaman, E.C., Jr., and A.J. Weber. 1973. Seasonal food habits of white-tailed deer in a treated eastern North Carolina pocosin. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 27:125–142.

Strole, T.A., and R.C. Anderson. 1992. White-tailed deer browsing: Species preferences and implications for central Illinois forests. Natur. Areas J. 12:139–144.

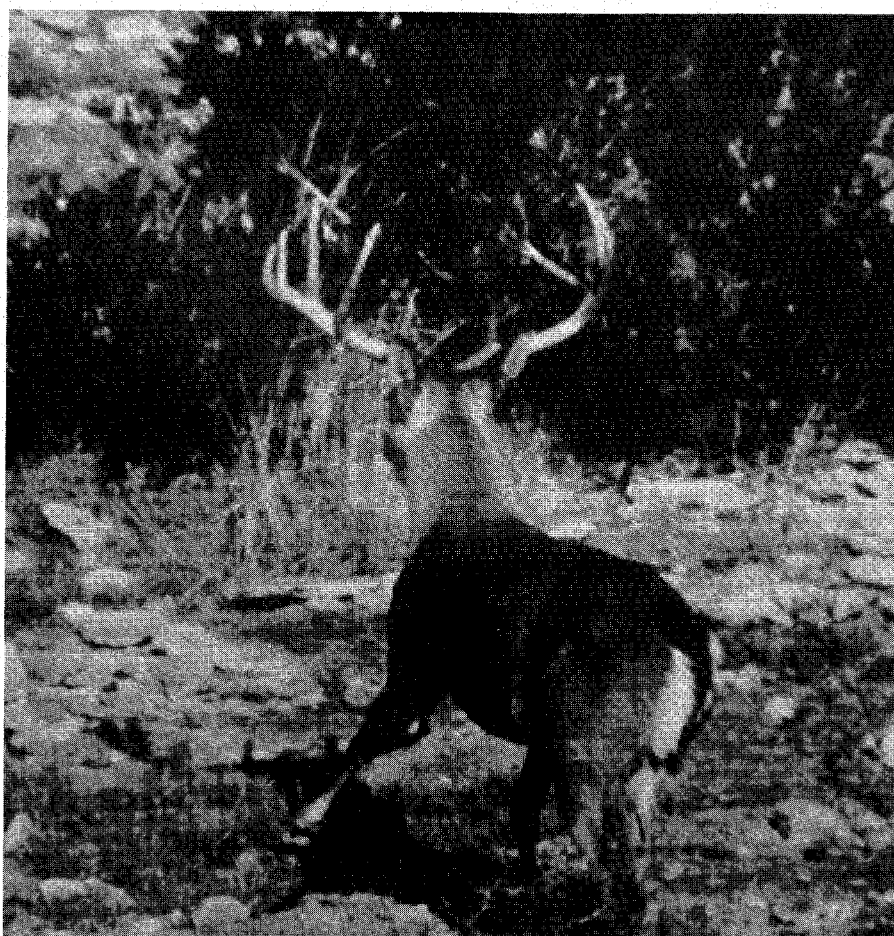
Tilghman, N.G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. J. Wildl. Manage. 53:524–532.

Van de Koppel, J.J. Huisman, R. van der Wal, and H. Olff. 1996. Patterns of herbivory along a productivity gradient: An empirical and theoretical investigation. Ecology 77:736–745.

Warren, R.C., and G.A. Hurst. 1981. Ratings of plants in pine plantations as white-tailed deer food. Miss. Agric. For. Exp. Sta. Inf. Bull. 18. Miss. State Univ. 14 p.

Basics of Brush Management for White-tailed Deer Production

By
Tommy L. Hailey
Technical Guidance Biologist



BASICS OF BRUSH MANAGEMENT FOR WHITE-TAILED DEER PRODUCTION

by Tommy L. Hailey

Technical Guidance Biologist

A Contribution of Federal Aid (P-R)
Project W-109-R

TEXAS PARKS AND WILDLIFE DEPARTMENT
WILDLIFE DIVISION
1979

BRUSH MANAGEMENT FOR WILDLIFE PRODUCTION

There are approximately 4 million white-tailed deer in Texas. This rather remarkable statistic is even more remarkable when one considers that there were relatively few deer in the state at the turn of the century.

The rise of the white-tailed deer has spawned a multi-million dollar recreational industry, furnishing thousands of hours of hunting recreation each fall. This abundance of deer in the past few decades is the result of radical changes in the state's ecology since the advent of the white man.

However, the ecological changes which ushered in this boom for whitetails now appear to be heading the other way.

To understand why the white-tailed deer expanded its range so rapidly, one needs to consider that most of Texas 100 years ago was dominated by grassland. Periodic range fires allowed the fast-growing grasses to dominate, keeping woody shrubs and trees confined to bottomland areas. As crops and livestock grazing became primary land uses in Texas, the grasslands were converted and as a result range fires were virtually eliminated. This opened the door for the entry of weeds and woody species of plants which provided the basic food and cover requirements of white-tailed deer.

Of course, protective hunting laws, elimination of large predators and management contributed to the meteoric rise of the whitetail as well.

But now biologists believe the danger signs are becoming increasingly apparent for the whitetail. Deer have overpopulated many areas, becoming too numerous for the available food and cover.

Increasing competition from livestock for forage and constantly encroaching civilization are easily documented as negative factors. Another problem which appears to be growing is that of brush clearing, both with machinery and more effective chemicals. Brushland areas of suitable deer habitat are being converted to pure grasslands or to farms, neither of which can sustain deer populations. Total eradication of brush simply means a total loss of deer habitat.

Excessive brush clearing results in an area which is unsuitable for wildlife species.

The economic benefits of brush control on productive soil sites are proven facts in most areas of the state, but total removal of all brush species on a ranch is disastrous to existing wildlife populations. In recent years, the value of ranch lands which have sufficient brush cover to support wildlife populations has increased at a faster rate than the value of those lands which are void of brush or woody vegetation. Multiple uses of the land for livestock production and outdoor recreation are major factors when considering land values. Many small tracts of land are being purchased for outdoor recreation with livestock production being given secondary consideration.

One of the questions often asked is, "Can I manage for both livestock and wildlife on a profitable basis?" The answer is most definitely, "Yes," and this is especially applicable on ranges where wildlife habitat and wildlife populations already exist. One of the primary objectives of a sound management program is to assure that plans provide for leaving adequate food and cover for wildlife during brush control operations. Wildlife will succeed only where their basic requirements of food and cover are satisfied.

Deer are primarily browsing ruminants. Browse such as stems, leaves, buds and bark of woody plants (both trees and brush) make up the bulk of the deer's diet during most of the year. Weeds, grass, seeds and fruits also are important food items. However, it should be pointed out that grasses in general constitute only a small percentage of a deer's total diet; therefore, a total grassland climax is not conducive to deer management.

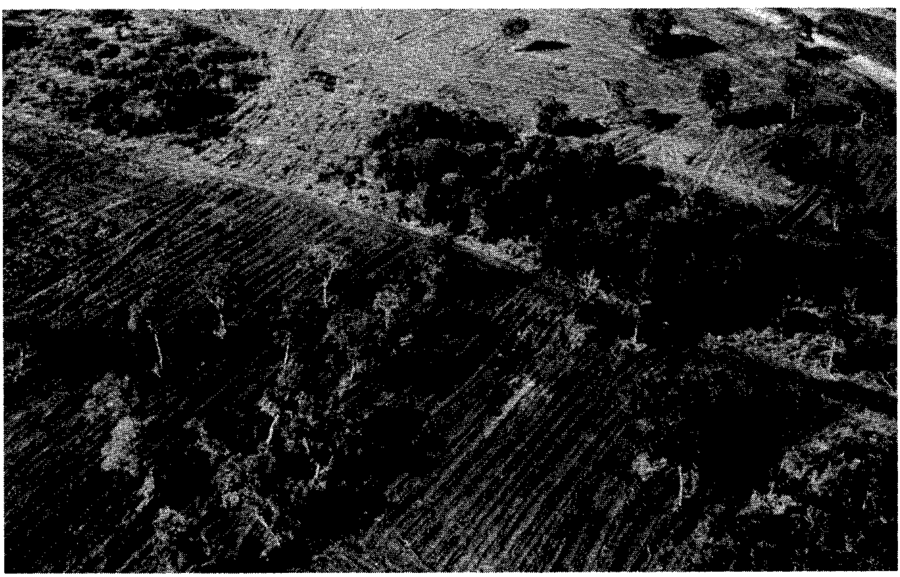
Deer have adapted to various forms of cover requirements. Herbaceous vegetation generally does not provide sufficient cover. Some type of woody cover must be readily available. Cover must furnish protection and security from man and weather as well as provide food.

Excellent edge effect created by properly planned or controlled clearing creates quality wildlife habitat.

In many instances, brush cleared from better soil types results in higher forage production at a lower rate of initial investment. The steeper slopes usually are rockier with thinner soils and do not respond readily to brush-control practices.

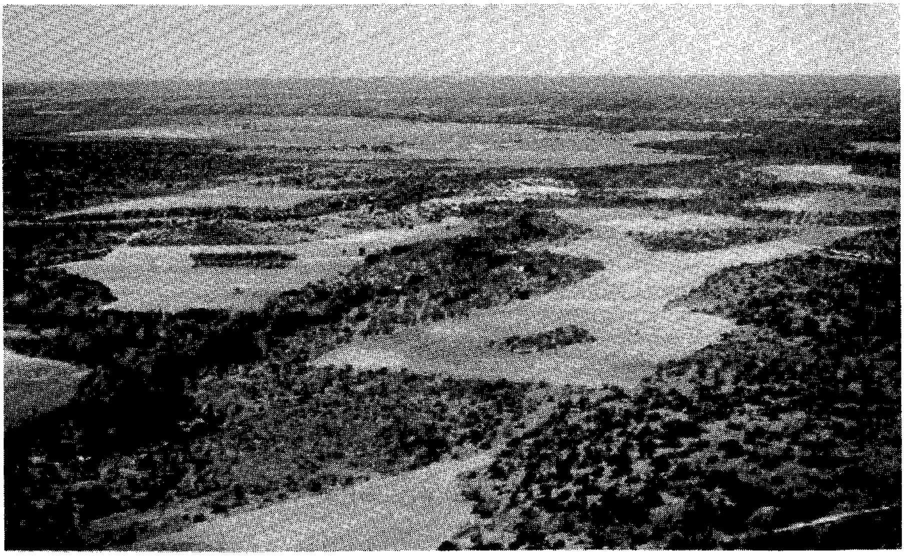
The types of brush-control patterns used will depend upon the terrain in the area to be treated. To a great degree, natural terrain features will dictate the types and conformation of patterns.

Before treatment - Dense brush area prior to clearing.



After treatment - This type of clearing blends in with the surrounding terrain and does not look as artificial as the straight strips.

Sufficient brush cover must be left along water courses which usually serve as wildlife travel lanes. The width of the strips to be left for most wildlife can be determined by visual inspection. The strips of brush to be left should be wide enough to prevent seeing through them at most points from December through February when most species have lost their leaves. All natural wildlife travel ways, which would include water courses, saddles between ridges, headers or canyon beginnings, extension of ridges and any unusual high-quality wildlife food plants should be left.



Drainages left in native cover to provide travel lanes, escape cover, resting areas and feeding sites.

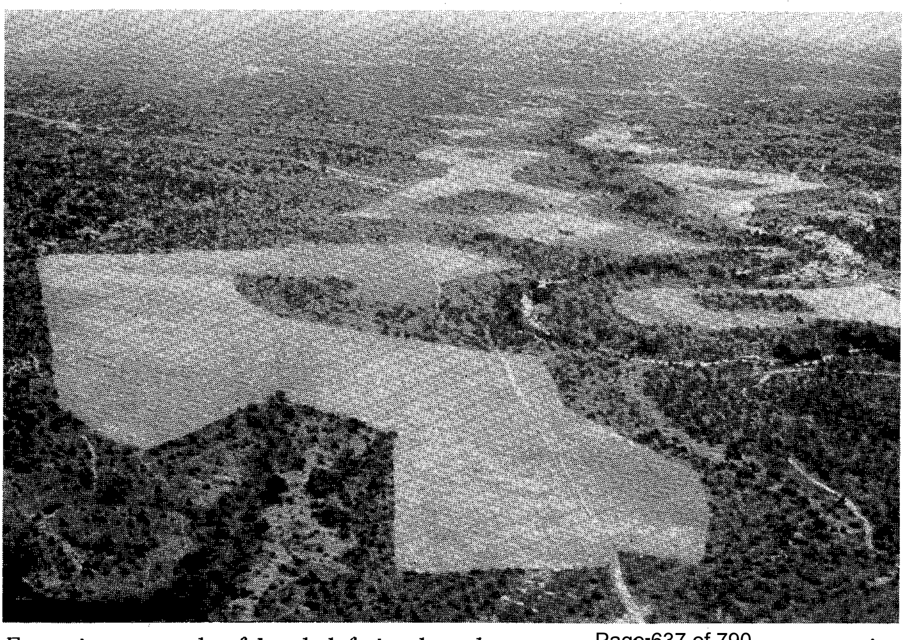
When cleared strips extend for great distances, a belt or block of brush should be left every 200 to 300 yards to break up the open spaces and provide covered travel lanes for wildlife connecting these strips.

In South Texas where the terrain is relatively flat with no prominent features, alternate strips of cleared areas and brush produce good results, although clearing in an irregular pattern is more desirable. The strips can be established on a 1:1 ratio, such as clearing 300 feet and leaving 300 feet of brush if the strips provide sufficient cover and food. In large areas the strips can be established in gently curving patterns to block excessive views, and belts or blocks of brush can be left at desirable intervals across cleared areas. Brush strips should be left along drainage areas or draws used as natural travel ways by wildlife.

Where cleared areas tend to be excessively large, islands of brush should be left interspersed within the cleared areas to provide escape cover. As with brush strips, the islands should be large enough that they cannot be seen through from December through February.

Where islands do not provide sufficient escape cover, extensions or necks of brush can be left for escape cover and travel ways to prominent terrain features frequented by wildlife.

Islands of brush left in cleared areas to provide escape cover, resting areas and feeding sites.



Extension or neck of brush left in cleared area to provide escape cover, resting areas and feeding sites.

During the initial planning of a brush-control operation, extreme care should be taken to retain the many different types of woody food and cover plants necessary to maintain a resident wildlife population of all species. For example, woody plants or brush species are necessary to wild turkey populations, not only as food-producing plants, but also as cover and roosting timber. All existing winter roost timber should be left standing. In association with this, brush and smaller trees under or adjacent to the roosting areas must be retained. Turkeys require cover as they enter and depart the roost and also while loafing under the roost trees. Sufficient quantities of food-producing woody species such as chittum, hackberry, lote bush, oak, pecan and elm, which play an important role in the diet of the wild turkey, also should be maintained.

The improvement of range conditions through brush management will increase the available food supply for wildlife and domestic livestock. This additional food supply will improve the quality of the animals being produced. Brush should be managed only in conjunction with sound range management practices. Brush-control measures without proper range management often prove to be more detrimental to the land and animals than no brush control at all.

Although some basic rules for brush management may be applied to all treated areas, the topography, types of vegetation and wildlife species present on each ranch unit and even from pasture to pasture within a ranch will be different. Therefore, an on-the-ground inspection of the entire ranch is necessary, prior to formulating sound management plans. A wildlife technical assistance specialist is stationed in each of the four wildlife administrative regions of the state, along with wildlife biologists located throughout Texas who are available to work directly with landowners in helping to plan and apply sound wildlife programs.

For further information contact Herbert G. Kothmann, Texas Parks and Wildlife Department, 4200 Smith School Road, Austin, Texas 78744 (Phone 512-389-4770.

PWD-BK-7100-35-12/88

WILDLIFE RESTORATION

Great Trinity Forest Management Plan

Wildlife Management

American Beaver

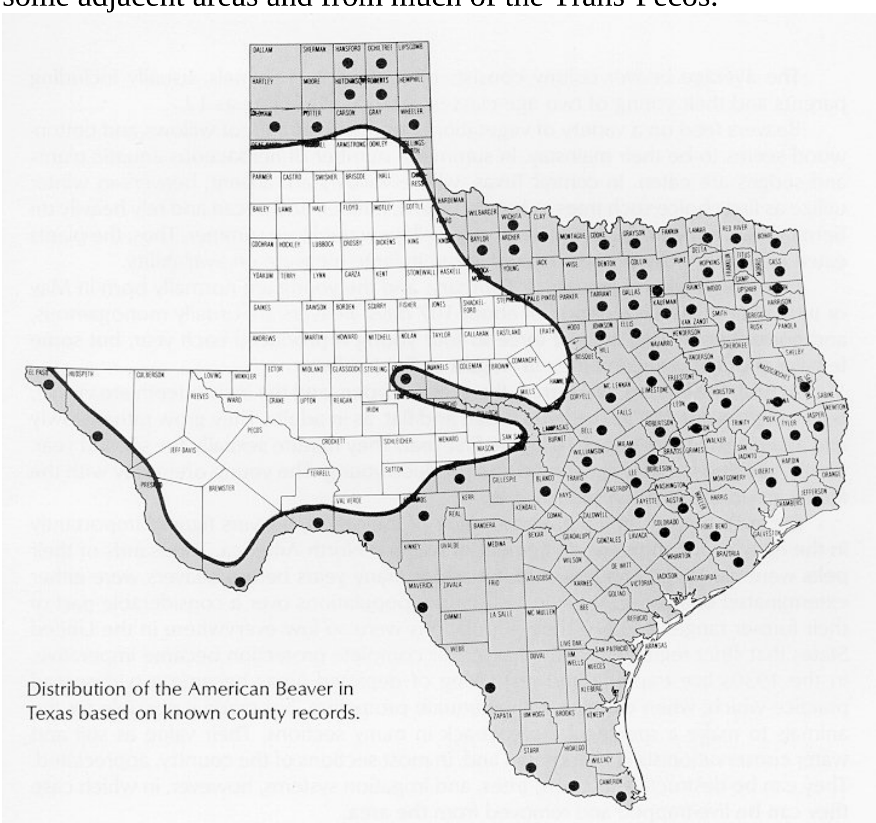
(Castor canadensis)

American Beaver

Order Rodentia : Family Castoridae :
Castor canadensis Kuhl

Description. A large, robust, aquatic rodent with a broad, horizontally flattened, scaly tail; hind feet webbed; upperparts in fresh fall pelage dark, rich, chestnut brown which fades by spring; underparts paler, often with silvery sheen. Sexes colored alike. External measurements average: total length, 1,160 mm; tail, 400 mm; hind foot, 178 mm. Weight, averages 18 kg; rarely as much as 27 kg. The dental formula is I 1/1, C 0/0, Pm 1/1, M 3/3 X 2 = 20.

Distribution in Texas. Found over most of the state where suitable aquatic habitat prevails; absent from the Llano Estacado and some adjacent areas and from much of the Trans-Pecos.



Distribution of the American Beaver in Texas based on known county records.

Habits. Beavers are essentially aquatic and require water in the form of a pond, stream, lake, or river for their well-being. Because of their skills in regulating water level and stream flow with dams, beavers are able to convert an otherwise unfavorable area into one that is habitable. But they must be ever alert as water engineers because their ponds tend to fill up with sediment washed off the slopes above and in time become meadows, forcing the beavers to move to new sites. Large rivers and lakes offer suitable habitat in places where natural food and den or house sites are available, but the largest populations are on small bodies of water.

In cold regions, beavers live in houses constructed of sticks and mud and enter and leave them by means of underwater tunnels or "plunge holes"; in Texas they may burrow into cut banks of streams or lakes. Burrows examined in the Rio Grande in the Big Bend section of Texas were large enough to admit a man and were 10 m or more in length. Burrows as long as 50 m have been reported. Burrows, or houses, are used for loafing, sleeping, and rearing the young.

The average beaver colony consists of six or seven animals, usually including parents and their young of two age classes; rarely is it as large as 12.

Beavers feed on a variety of vegetation, but the inner bark of willows and cottonwood seems to be their mainstay. In summer a number of herbaceous aquatic plants and sedges are eaten. In central Texas, where willows are absent, beavers in winter utilize as first choice such trees as button willow, juniper, and pecan and rely heavily on Bermuda grass, beard grass, ragweed, and yellow water lily in summer. Thus, the plants eaten and their order of preference depend in large measure on availability.

Breeding begins in January or February, and the young are normally born in May or June after a gestation period of about 107 days. Beavers are usually monogamous, and normally only one litter of three to four young is produced each year, but some females produce a second litter in August or September.

At birth the kits are fully furred, the eyes are open, and the incisor teeth are visible; they weigh about 450 g. The tail is broad and flat, as in adults. They grow rather slowly and attain a weight of about 10 kg the first year. They mature sexually the second year. Rarely, yearling females may breed and produce young. The young often stay with the family group through the second year.

Because of the high commercial value of their pelts, beavers figured importantly in the early exploration and settlement of western North America. Thousands of their pelts were harvested annually, and it was not many years before beavers were either exterminated entirely or reduced to very low populations over a considerable part of their former range. By 1910 their populations were so low everywhere in the United States that strict regulation of the harvest or complete protection became imperative. In the 1930s live trapping and restocking of depleted areas became a widespread practice which, when coupled with adequate protection, has made it possible for the animals to make a spectacular comeback in many sections. Their value as soil and water conservationists is well-known and, in most sections of the country, appreciated. They can be destructive to crops, trees, and irrigation systems, however, in which case they can be live-trapped and removed from the area.

Photo credit: John L. Tveten.

Great Trinity Forest Management Plan

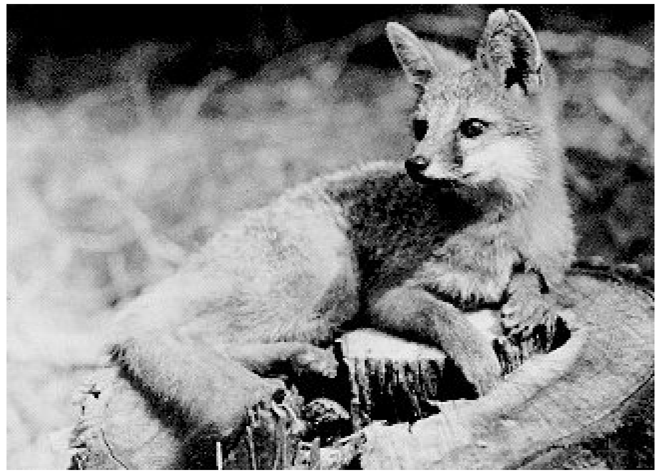
Wildlife Management

Common Gray Fox

(Urocyon cinereoargenteus)

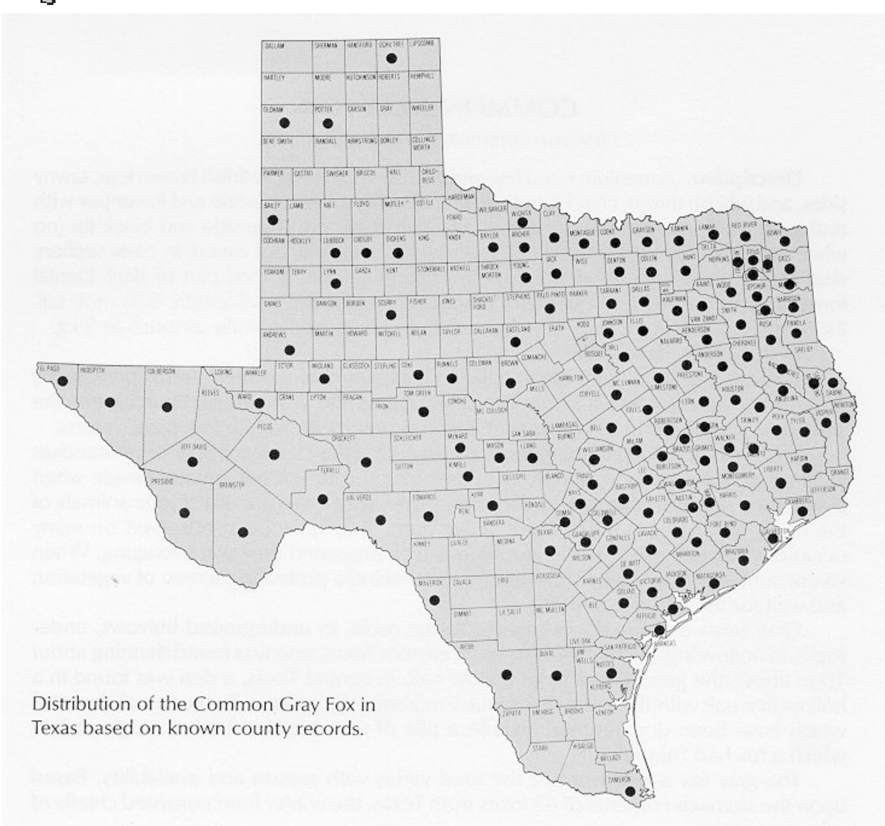
Common Gray Fox

Order Carnivora : Family Canidae :
Urocyon cinereoargenteus (Schreber)



Description. A medium-sized fox with grayish upperparts, reddish brown legs, tawny sides, and whitish throat, cheeks and mid-line of belly; sides of muzzle and lower jaw with distinct blackish patch; tail with distinct blackish stripe on upperside and black tip (no white on end of tail as in the red fox); tail roughly triangular, not round, in cross section; skull with distinct lyrate temporal ridges, which meet only at hind part of skull. Dental formula as in the red fox. External measurements average: total length, 970 mm; tail, 347 mm; hind foot, 143 mm. Weight, ordinarily 3-5 kg, occasionally as much as 9 kg.

Distribution in Texas. Statewide.



Distribution of the Common Gray Fox in Texas based on known county records.

Habits. The gray fox is essentially an inhabitant of wooded areas, particularly mixed hardwood forests. It is common throughout the wooded sections east of the shortgrass plains and in the pinyon-juniper community above the low lying deserts.

This fox is adept at climbing trees, particularly if they are leaning or have branches within 3 m of the ground, and it is not unusual for it to use this escape device when pursued by hounds. Contrary to common belief, gray foxes are not strictly animals of the night, but they are much more active then. They have been observed on many occasions in the daytime under conditions that suggested they were foraging. When so encountered, they often move to one side behind a protecting screen of vegetation and wait for the intruder to pass.

Gray foxes usually den in crevices in the rocks, in underground burrows, under rocks, in hollow logs, or in hollow trees. In eastern Texas, one was found denning about 10 m above the ground in a large hollow oak. In central Texas, a den was found in a hollow live oak with the entrance about 1 m above the ground. Two unusual den sites which have been documented include a pile of wood and a field of sorghum into which a fox had "tunneled."

The gray fox is omnivorous; the food varies with season and availability. Based upon the stomach contents of 42 foxes from Texas, the winter food consisted chiefly of small mammals (cottontails, cotton rats, pocket gophers, pocket mice), 56%; followed by insects, largely grasshoppers, 23%; and birds (doves, quail, sparrows, blackbirds, towhees), 21%. In the spring the diet was but slightly changed — small mammals, 68%; insects, 25%; small birds, 17%. In late summer and fall, persimmons and acorns led with 30%; insects, 26%; small mammals, 16%; birds, 14%; crayfish, 14%. In these 42 stomachs, chicken and quail occurred once each, and mourning doves twice. Consequently, as judged from these analyses, the usual food habits of the gray fox do not conflict much with man’s economy.

In Texas, the breeding season begins in December and continues on into March. Most females captured in March and April are gravid. The three to six pups are born in April or May after a gestation period of about 53 days. At first they are blind and helpless, but they grow rapidly and soon leave the home nest, possibly because of the heavy infestation of fleas characteristic of such nests. Then they seek shelter in rock piles, under rocks, in piles of brush, or in other sites that offer concealment and protection.

Of some interest is the possible relationship between gray foxes and coyotes. In sections of Texas where coyotes formerly were numerous, the gray fox was scarce; now, after elimination of the coyote, the gray fox has become abundant. Perhaps the coyote tends to hold this fox in check under conditions where they both occupy the same area.

Gray foxes are thought to live six to 10 years in the wild. Major factors causing mortality include predation, parasites, diseases, and man. The gray fox is among the most important of Texas’ fur-bearing animals.

Photo courtesy of U.S. Fish and Wildlife Service.

Great Trinity Forest Management Plan

Wildlife Management

Cotton Mouse

(*Peromyscus gossypinus*)

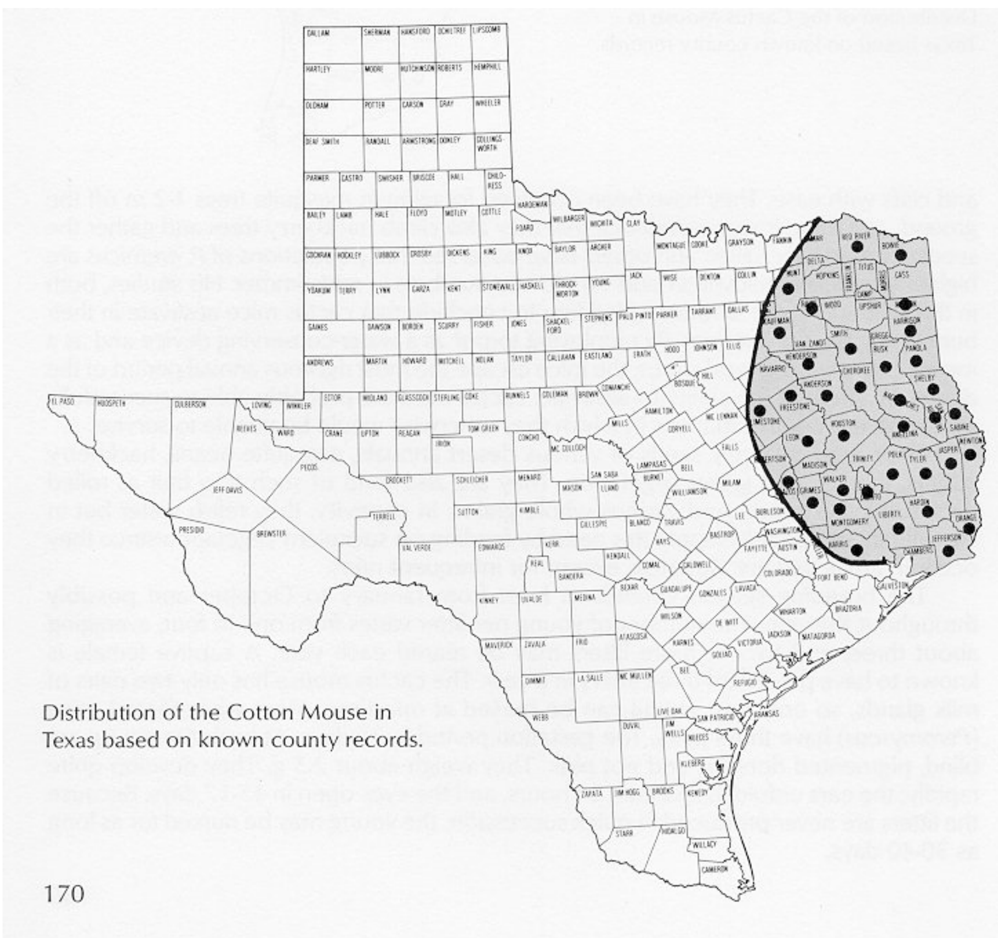
Cotton Mouse

Order Rodentia : Family Muridae : *Peromyscus gossypinus* (Le Conte)

Description. A medium-sized, heavy bodied, white-footed mouse; tail much shorter than head and body, between three and four times the length of hind foot and not sharply bicolor, but darker above than below; ears small (16-18 mm from notch); upperparts mummy brown, the mid-dorsal area suffused with black; sides bright russet; underparts creamy white; feet white, but tarsal joint of heel dark like leg. External measurements average: total length, 180 mm; tail, 78 mm; hind foot, 23 mm. Weight, 34-51 g.

This mouse is most easily confused with the white-footed mouse (*Peromyscus leucopus*), from which it can be distinguished by larger size (weight usually over 30 g in adults as opposed to 15-25 g in *leucopus*) and longer skull (27 mm or more in *gossypinus* and less than that in *leucopus*).

Distribution in Texas. Found in woodlands in eastern one-fourth of state.



Distribution of the Cotton Mouse in Texas based on known county records.

Habits. Cotton mice are typically woodland dwellers and occur along water courses where stumps, down logs, and tangles of brush and vines offer suitable retreats; frequently they occur in woodland areas bordering open fields. They have been trapped in eastern Texas in canebrakes, under logs, and around and in old, tumbledown buildings in wooded areas. That they are adept at climbing and may live off the ground in hollows in trees as indicated by the capture of individuals in live traps set on platforms in trees.

Their other habits are not well-known. Nothing specific is known of their natural foods, although cotton mice are omnivorous. Over one-half of their diet may be made up of animal matter and food availability probably determines the dietary composition. Captive mice seemed to relish rolled oats, wheat, corn, and bread. Green foods were eaten sparingly.

Breeding may occur throughout the year although there is a decline in reproductive activity during the summer months. In Texas, most breeding commences in late August, reaches a peak in November, December, and January and subsides by early May. The gestation period is about 23 days in non-nursing females and about 30 days in females which are nursing a previous litter. Adult females may produce four or more litters a year. The litter size ranges from one to seven and averages three or four. The young are naked and blind at birth. Their ears open in 5 or 6 days at which age their incisor teeth erupt. Their eyes open in about 13 days and shortly after that they begin to eat solid foods. They are completely weaned at an age of 20-25 days. They become sexually mature at about 60-70 days of age.

The name cotton mouse was applied to the species by Le Conte, who found that the mice often used cotton for nest construction. Ordinarily, however, they do little or no damage to cotton or foodstuffs.

<u>Great Trinity Forest Management Plan</u>

Wildlife Management

Coyote

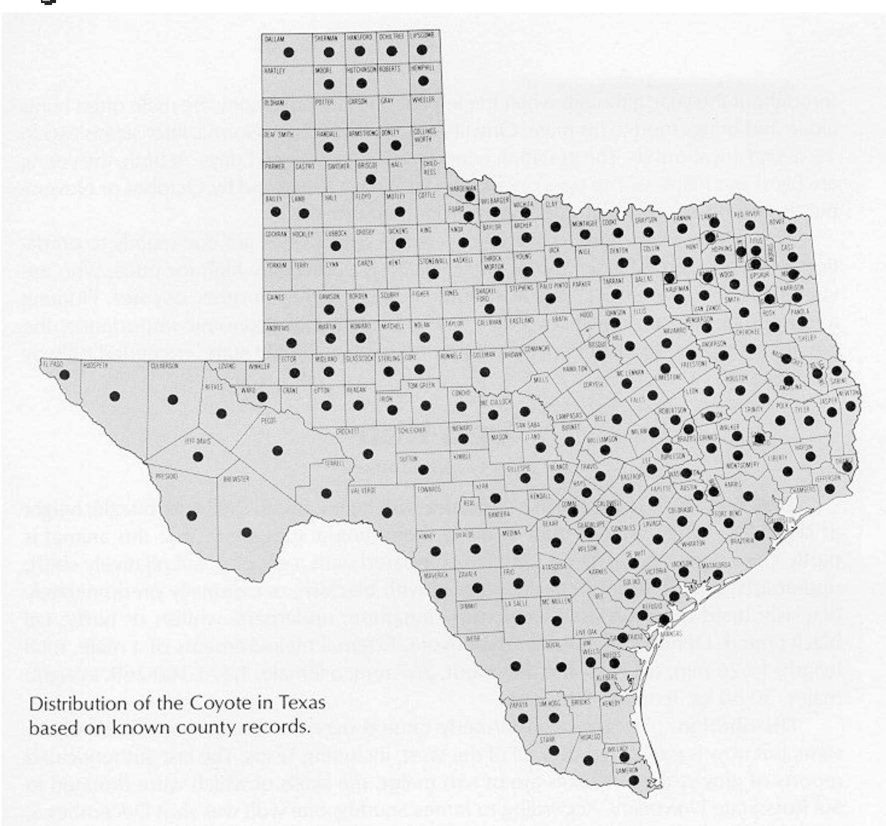
(<u>Canis</u> <u>latrans</u>)

Coyote

Order Carnivora : Family Canidae : *Canis latrans* Say

Description. A medium-sized, slender, doglike carnivore, similar in appearance to the red wolf* but usually smaller, more slender, with smaller feet, narrower muzzle, and relatively longer tail; colors usually paler, less rufous, rarely blackish; differs from gray wolves in much smaller size, smaller feet and skull; upperparts grizzled buffy and grayish overlaid with black; muzzle, ears and outersides of legs yellowish buff; tail with black tip, and with upperpart colored like back. Dental formula: I 3/3, C 1/1, Pm 4/4, M usually 2/2, occasionally 3/3, 3/2, or 2/3 X 2 = 40, 42, or 44. External measurements average: total length, 1,219 mm; tail, 394 mm; hind foot, 179 mm. Weight, 14-20 kg.

Distribution in Texas. Statewide.



Distribution of the Coyote in Texas based on known county records.

Habits. Although often called "prairie wolf," the extensive range of the coyote includes from sea level to well over 3,000 m and habitats ranging from desert scrub through grassland into the timbered sections of the West. Around the turn of the century, coyotes were not known in eastern Texas, where red wolves were common. Land use in this area, including intensive lumbering and agriculture, as well as intensive predator control, eradicated the wolves and now coyotes have expanded their range to also include that part of the state.

The basic social unit is the family group, comprised of a mated pair and their offspring. Nonfamily coyotes include bachelor males, nonreproductive females, and near-mature young. They may live alone or form loose associations of two to six animals. One animal in such "packs" usually is dominant, but the interaction among pack members is only temporary.

Coyotes may be active throughout the day, but they tend to be more active during the early morning and around sunset. Their movements include travel within a territory or home range, dispersal from the den, and long migrations. The home range size of coyotes varies geographically, seasonally, and individually within populations.

The food habits of coyotes are varied. They are opportunists and make use of anything that can be eaten — garbage, carrion, fresh meat in the form of both wild and domestic animals, insects, frogs, snakes, fruits, melons, and so forth. Although coyotes prey on poultry and the smaller livestock, their natural foods consist largely of rabbits, rodents, and carrion. Charles Sperry analyzed 8,339 stomachs of coyotes from the western United States with the following results (expressed in percentages): rabbits, 33; carrion, 25; rodents, 18; domestic livestock (chiefly sheep and goats), 13.5; deer, 3.5; birds, 3; insects, 1; other animal matter (skunks, weasels, shrews, moles, snakes, and lizards), 1; vegetable matter, 2.

Nursery dens are usually located in brush covered slopes, steep banks, thickets, hollow logs, or rock ledges. One den was in a hollow cottonwood tree with the entrance 5 m above the ground. Access to this unusual den was gained by means of a large limb that sloped to the ground. They are also known to den in crevices and shallow caves in rocky bluffs. Rarely is no den provided for the young.

The breeding season begins in January, reaches its peak in late February or early March, and terminates by the middle of May. Coyote mates maintain a close social bond throughout the year, although when the female is in late pregnancy the male often hunts alone and brings food to his mate. One litter a year is the rule. Normal litter size is two to 12, averaging about six. The gestation period is approximately 63 days. At birth, the young are blind and helpless. The eyes open at about 9 days of age and by October or November the young are difficult to distinguish from their parents.

Few coyotes live more than 6-8 years in the wild. Losses are due mainly to predation, parasites and disease, and man. Mortality is particularly high for pups, who are vulnerable to hawks, owls, eagles, mountain lions, and even other coyotes. Hunting and trapping account for many adult deaths. In terms of economic importance, the coyote is the second most important furbearing animal in the state, exceeded only by the raccoon.

* *see the Red Wolf species entry for a detailed comparison of the two animals.*

Photo credit: John L. Tveten.

Great Trinity Forest Management Plan

Wildlife Management

Eastern Gray Squirrel

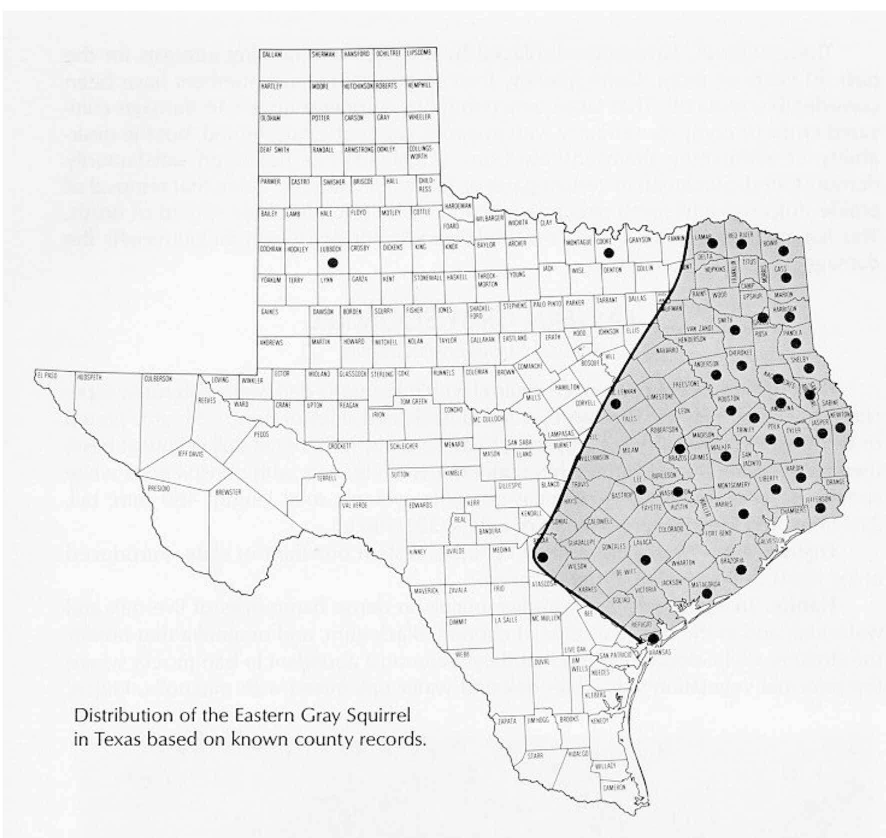
(Sciurus carolinensis)

Eastern Gray Squirrel

Order Rodentia : Family Sciuridae :
Sciurus carolinensis (Gmelin)

Description. A medium-sized squirrel with upperparts dark yellowish rusty, especially on head and back; legs, arms, sides of neck, and sides of rump with gray-tipped or white-tipped hairs, giving a gray tone to these parts; hairs of tail dull yellow at base, then blackish, and tipped with white; underparts white; ears with conspicuous white spot at base in winter. External measurements average: total length, 460 mm; tail, 210 mm; hind foot, 61 mm. Weight of adults, 321-590 g.

Distribution in Texas. Native distribution includes eastern one-third of state. Introduced at locations to the west of its native range.



Distribution of the Eastern Gray Squirrel in Texas based on known county records.

Habits. In Texas, gray squirrels live mainly in dense hammocks of live oak and water oak and in the deep swamps of cypress, black gum, and magnolia that border the streams. Phil Goodrum found that they were most abundant in hammocks where the principal vegetation was white oak and water oak mixed with magnolia, linden, sweet gum, and holly. Poorly drained bottom lands with their pin, evergreen and overcup oaks, elms, bitter pecan, black gum, cypress, and ash support much smaller populations. In well-drained bottom lands with post and red oaks, hackberries, gum elastic, and pecan, the populations are still smaller, and upland forests usually are devoid of gray squirrels.

They den in hollow trees when available, but they also utilize outside leaf nests, especially in spring and summer. These serve usually as refuge, resting and feeding stations and occasionally as nurseries. Placed in trees, they are constructed of twigs, leaves, and so forth on the outside and lined with shredded bark, plant fibers, and grasses. Usually there are two openings.

Gray squirrels feed on a variety of foods, chiefly plant in origin. Goodrum lists buds and mast of oak and pecan trees, grapes, fungi, red haw buds, sedges, grasses, mulberry, larval and adult insects, and amphibians. Their mainstay, however, is mast (acorns, etc.). They begin eating acorns in the Spring and continue throughout the year if they are available. When mast crops fail in one area, the squirrels usually move en masse to other areas where food is more abundant. This accounts in large measure for the "migrations" of squirrels that are frequently reported. Normally they feed twice a day — early morning and late afternoon — and are less active at midday.

These squirrels breed throughout the year, but there are two rather distinct peaks — July, August, and September and again in December, January, and February. Mating is more or less promiscuous; several males usually attempt to mate with each receptive female. After a gestation period of 40-45 days, the two to four naked, blind, and helpless young are born. They remain in the nest for about 6 weeks by which time their eyes are open and their teeth have developed so they can eat solid foods. By that time they weigh about 200 g. They remain in family groups for a month or so after they begin foraging for themselves. When 6 months old they are nearly adult in size and have left the home territory. They mature sexually in their first year and produce young of their own when about 12 months old.

These squirrels are highly prized as game. In most parts of their range they are decreasing in numbers because of overhunting and the removal of favored habitat by drainage or lumbering operations. Consequently, sound management of their habitat is becoming an increasingly important responsibility. Their future will depend upon the acreage remaining in hardwood forests, the length of timber rotations, the species composition of hardwood stands, and the abundance of mast supplies and dens. They do some damage in pecan orchards, but such depredations are local in nature and can usually be minimized by placing tin shields around the trunks which prevent the squirrels from climbing trees.

Photo courtesy of Texas Parks and Wildlife.

Great Trinity Forest Management Plan

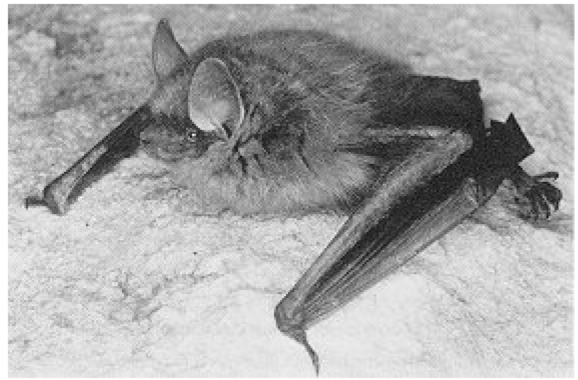
Wildlife Management

Eastern Pipistrelle

(Pipistrellus subflavus)

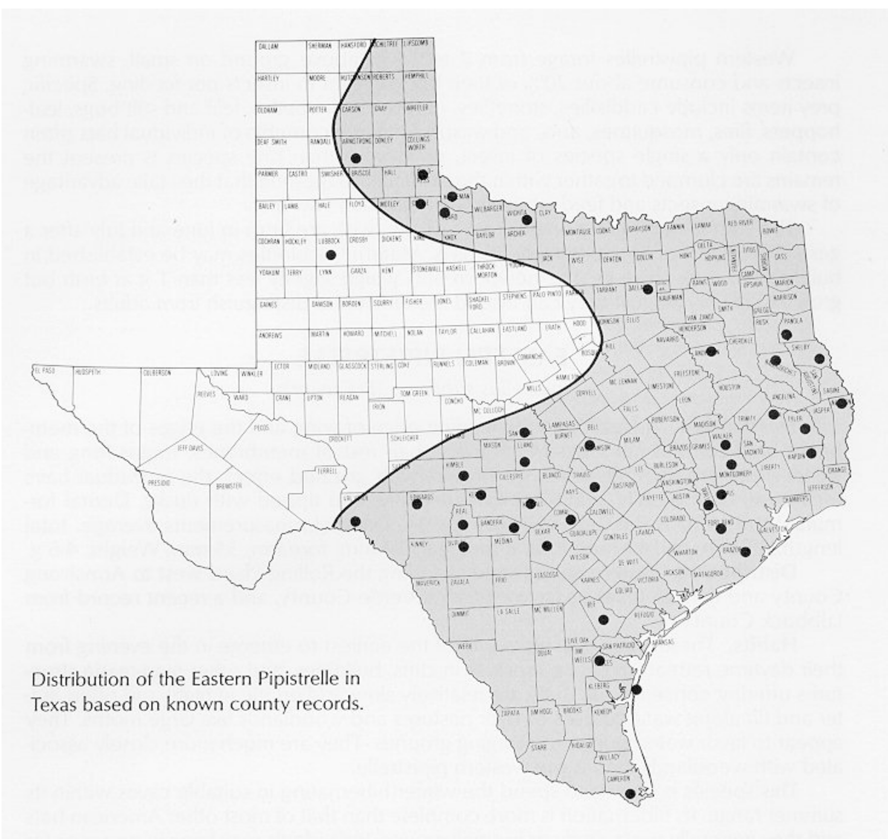
Eastern Pipistrelle

Order Chiroptera : Family Vespertilionidae :
Pipistrellus subflavus (F. Cuvier)



Description. A small bat with leading edge of wing and the edges of the membrane between the hind legs much paler than rest of membranes; tragus long and slender; upperparts pale yellowish brown, with grizzled effect; the individual hairs tricolored, dark basally, grayish-yellow medially, and tipped with dusky. Dental formula: I 2/3, C 1/1, Pm 2/2, M 3/3 X 2 = 34. External measurements average: total length, 85 mm; tail, 41 mm; foot, 8 mm; ear, 14 mm; forearm, 35 mm. Weight, 4-6 g.

Distribution in Texas. Eastern half of state including the Rolling Plains west to Armstrong County and central Texas as far west as Val Verde County, and a recent record from Lubbock County.



Distribution of the Eastern Pipistrelle in Texas based on known county records.

Habits. These small bats are some of the earliest to emerge in the evening from their daytime retreats in caves, crevices in cliffs, buildings, and other man-made structures offering concealment. They are relatively slow and erratic in flight and often flutter and flit along watercourses or over pastures and woodlands like large moths. They appear to favor watercourses as foraging grounds. They are much more closely associated with woodlands than is the western pipistrelle.

This species is known to spend the winter hibernating in suitable caves within its summer range. Its hibernation is more complete than that of most other American bats and they generally roost singly or in small groups. Individuals may hang in one spot for weeks on end, and their torpor is so deep that they are not easily disturbed. They emerge from hibernation early in the spring and remain active well into the fall.

Little is known of their food habits in Texas. In Indiana they are known to eat small leafhoppers, ground beetles, flies, moths, and ants. Insects are caught by the bats in considerable quantities in a short period and within 20 minutes they are gorged. They probably feed at intervals throughout the night and hang up to digest their meals between feeding times.

Mating takes place in the fall. They have been observed copulating as late as November. Both males and females have been observed roosting together as early as August, however. During the period from March to August adult males and females usually occupy separate roosts. Data suggest that the sperm may remain viable in the vaginal tract of the female until spring, when ovulation occurs (in March or April) and fertilization of the ova takes place. However, copulation in the spring also has been observed.

The exact period of gestation is not known, but it probably does not begin until the bats have left their winter quarters. The young, usually two in number, are born from May to July. They grow rapidly and when about 3 weeks old are able to take care of themselves.

Photo credit: John L. Tveten.

Great Trinity Forest Management Plan

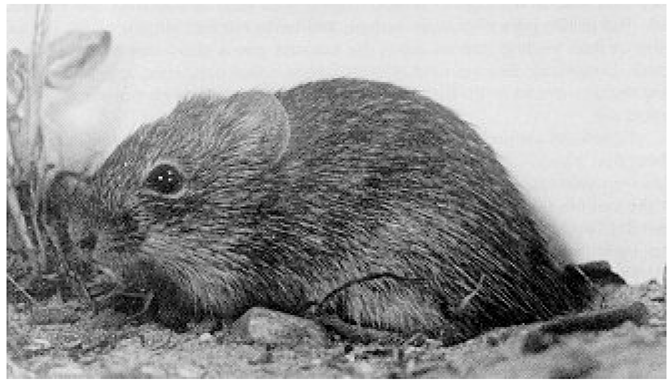
Wildlife Management

Hispid Cotton Rat

(Sigmodon hispidus)

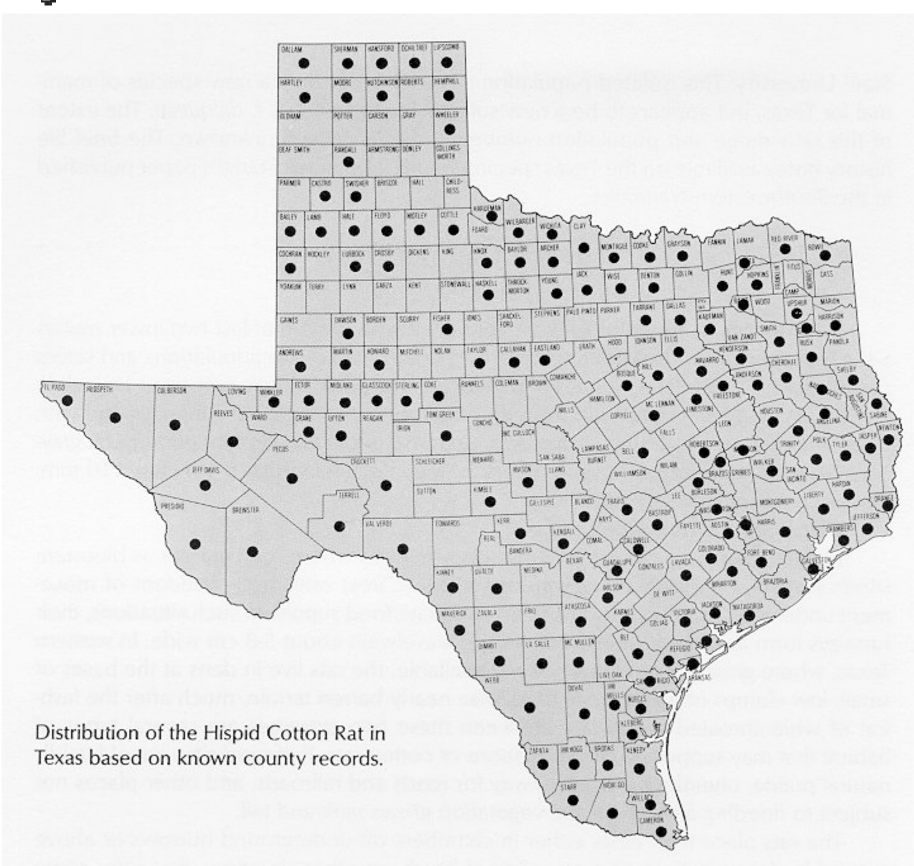
Hispid Cotton Rat

Order Rodentia : Family Muridae :
Sigmodon hispidus Say and Ord



Description. A moderately large, robust rat with pattern of last two lower molars S-shaped; tail shorter than head and body, sparsely haired, the annulations and scales clearly visible; ears relatively small and blackish or grayish; pelage coarse and grizzled, the black guard hairs rather stiff (hispid); hind foot with six plantar tubercles and with three middle toes longer than outer two; upperparts grizzled brown; underparts grayish white or buff. External measurements average: total length, 270 mm; tail, 110 mm; hind foot, 31 mm. Weight, 80-150 g.

Distribution in Texas. Statewide.



Distribution of the Hispid Cotton Rat in Texas based on known county records.

Habits. Normally this rat inhabits tall-grass areas where such grasses as bluestem (*Andropogon*), cordgrass (*Spartina*), or sedges (*Carex*) offer both freedom of movement under a protective canopy and an adequate food supply. In such situations, their runways form a network of interconnecting travelways about 5-8 cm wide. In western Texas, where grassy ground cover is not available, the rats live in dens at the bases of small, low clumps of mesquite in otherwise nearly barren terrain, much after the fashion of white-throated wood rats. Between these two extremes are several types of habitat that may support small populations of cotton rats. Preferred sites are old fields, natural prairie, unmolested rights-of-way for roads and railroads, and other places not subject to flooding and where the vegetation grows rank and tall.

The rats place their nests either in chambers off underground burrows or above ground in dense clumps of grass, piles of brush, or other situations that offer some concealment and protection. The nests are globular, about 12 cm in diameter and composed of shredded grasses and weeds. Underground burrows are from 3-5 cm in diameter, simple in design, and seldom longer than 8 m. Occasionally, the rats take over and use the discarded burrows of pocket gophers and moles.

Their food is almost exclusively plant material, but there is some evidence that they feed also on the eggs of ground-nesting birds such as bobwhite and meadow lark. The telltale piles of grasses, sedges, and herbs cut into lengths of 5-8 cm and piled at their feeding stations along the runways give a good clue to their natural foods. In captivity, they are fond of most greens, rolled oats, corn, apples, potatoes, dog biscuits, and so forth. They are active the year round and do not store food for winter use.

Cotton rats are prolific and produce several litters of two to 10 young, averaging about five, a year. Captive females have given birth to as many as nine litters a year; data from wild-caught rats likewise indicate a nearly yearlong breeding season at least in the warmer parts of their range. The gestation period is approximately 27 days. Females frequently breed again immediately after partus. At birth the young are hairless, for the most part, pink, blind, and weigh about 5 g. They develop rapidly. The eyes open in about 36 hours, the incisors erupt on the fifth or sixth day, and the young rats are usually weaned when 15 or 20 days old. They can be successfully weaned, however, as soon as the teeth have erupted (5-6 days). Sexual maturity is reached in about 40 days when the animals are still in juvenile pelage; 6-month-old rats are indistinguishable externally from adults.

Cotton rats are subject to violent fluctuations in numbers. The last serious outbreak in Texas occurred in 1958 when millions of these rodents seemed to appear from nowhere and caused serious losses to farm crops, particularly peas, peanuts, watermelons, and cauliflower — as much as 90% loss in some instances.

Normally, cotton rats occur in moderate to low populations in all parts of the state where ground cover is present. The size of the population is correlated with the amount of suitable habitat, and suitable habitat in turn is correlated with the amount of rainfall. Thus, in the marginal parts of its range this rat is attuned to climatic changes and the population is subject to violent fluctuations. In fact, peak populations are recorded about every 10 years in central Texas. Records reveal a severe outbreak in 1919. Lesser peaks were reported in the late 1930s and again in the late 1940s. During the 7-year drought that began about 1950, cotton rat populations in central Texas were low because there were few places where they could live in numbers. Ground cover was sparse or even absent over most of their range west of a line drawn from Fort Worth to San Antonio and Corpus Christi.

When the rains came in 1957 they were a blessing, not only to the ranchers, but also to the cotton rat. Ground cover increased, providing better cover and more nutritious green food, and the cotton rat population took off. More of the youngsters in each litter could survive and produce young of their own. Because green food was available in quantity during most of 1957 and well into 1958, females were able to produce more and larger litters than normally. By late May 1958, they were found in unbelievable numbers in especially favorable areas. Estimates were as high as several hundred rats per hectare.

This rate of increase sounds fantastic, but is not difficult to comprehend when one is aware of the reproductive potential of these rats. Let's repeat some data for emphasis. An adult female may breed throughout the year in Texas when conditions are favorable. She may produce as many as nine litters of 10 young each (normally less). The gestation period is only 4 weeks, and the female breeds again within a few hours after giving birth. Young females are sexually mature in 40 days and can be mothers at the tender age of 68 days and grandmothers at 136 days! Thus, if we assume a new generation of cotton rats every 68 days, a female could be a great-great-great-grandmother at the age of 1 year and be the ancestor of about 15,500 cotton rats. If this same rate of reproduction were extended for only three more generations and all survived, the grand total of offspring from the original female would be more than 3½ million!

Although this potential is always present in cotton rats, it is seldom realized because of death due to predators, disease, lack of suitable or sufficient food, accidents, smaller litters, fewer litters a year, and so on. But when conditions are just right, the population "explodes," and we are hip deep in cotton rats before we know it.

Fortunately, every eruption is followed by a crash in the population that is brought on by a combination of factors, principally disease. Predators such as coyotes, bobcats, hawks, owls, and certain snakes take their toll, but the main killer is disease. As the rats increase in numbers, the animals become more and more crowded and provide more contacts for the rapid spread of disease. At the same time, the virulence of the disease increases until finally the crash occurs and the population is low once again.

Great Trinity Forest Management Plan

Wildlife Management

Mink

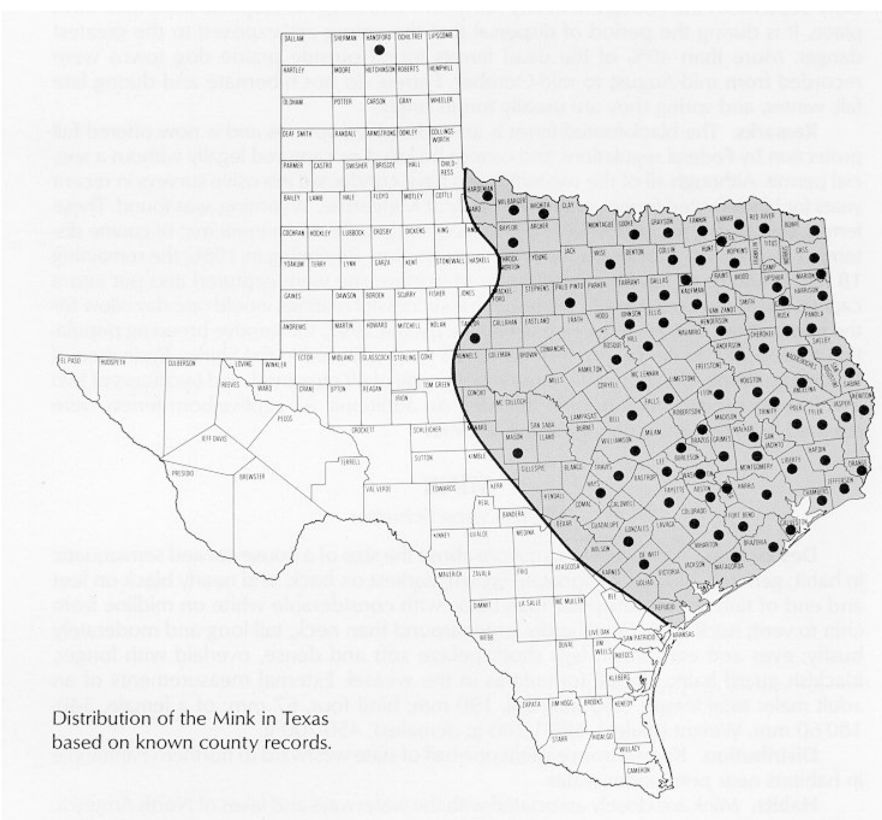
(Mustela vison)

Mink

Order Carnivora : Family Mustelidae
: *Mustela vison* Schreber

Description. A weasel-like carnivore about the size of a house cat and semiaquatic in habit; general color dark chocolate brown, darkest on back, and nearly black on feet and end of tail; underparts paler than back, with considerable white on midline from chin to vent; neck long, head hardly larger around than neck; tail long and moderately bushy; eyes and ears small; legs short; pelage soft and dense, overlaid with longer, blackish guard hairs. Dental formula as in the weasel. External measurements of an adult male: total length, 560 mm; tail, 190 mm; hind foot, 67 mm; of a female, 540-180-60 mm. Weight (males), 680-1,300 g; (females), 450-700 g.

Distribution in Texas. Known from eastern one-half of state westward to northern Panhandle in habitats near permanent water.



Distribution of the Mink in Texas based on known county records.

Habits. Mink are closely associated with the waterways and lakes of North America, but the smaller streams are preferred to the large, broad rivers. Along the coast they frequent the brackish marshes and, on occasion, the littoral area adjacent to the ocean. They are most common along streams partly choked by windfalls and other debris which create numerous water holes and at the same time offer concealment for the mink. Lake and marsh-dwelling mink are usually larger than those that live along streams.

Mink are active throughout the year. They are tireless wanderers and may travel several kilometers in their search for food.

The den is usually a retreat under the roots of a tree near the water, in a hole in the bank of a stream, in a pile of debris choking a stream, or in the houses of muskrats, which they kill or otherwise evict from their dens.

Their food consists of a wide variety of animals which they usually capture and kill. The fact that they are attracted to traps by carcasses of birds and other animals suggests that they also feed on carrion. Fish, frogs, clams, freshwater mussels, snakes, rats and mice, ground squirrels, muskrats, and birds constitute their main diet.

Mink are polygamous. The mating season is in January, February, and March and the four to eight young are born after a gestation period of from 39 to 76 days. At birth the young are blind, helpless, and covered with a coat of fine, short, silvery-white hair. They weigh about 6 g. When they are about 2 weeks old, the whitish hair is replaced by a dull, fluffy, reddish brown coat which, late in the year, is replaced by the adult pelage. Their eyes open at about 37 days of age and they leave the nest for the first time when about 7 weeks old. They are weaned when 8 or 9 weeks of age, at which time they weigh about 350 g. When about 5 months old, they are as large as adults.

The mink is one of the principal fur-bearing animals in the eastern United States and is one of the few animals that can be reared economically on fur farms. This is not the case in Texas, however, where mink ranked only thirteenth in numbers of individuals harvested and ninth in economic value to trappers during the 1988-89 trapping season, as determined in a survey conducted by the Texas Parks and Wildlife Department.

Photo credit: Donald F. Hoffmeister, courtesy of Museum of Natural History, University of Illinois.

Great Trinity Forest Management Plan

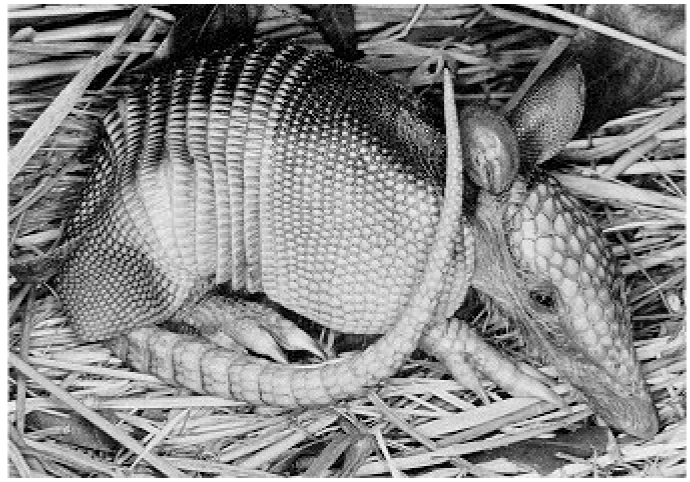
Wildlife Management

Nine-banded Armadillo

(Dasypus novemcinctus)

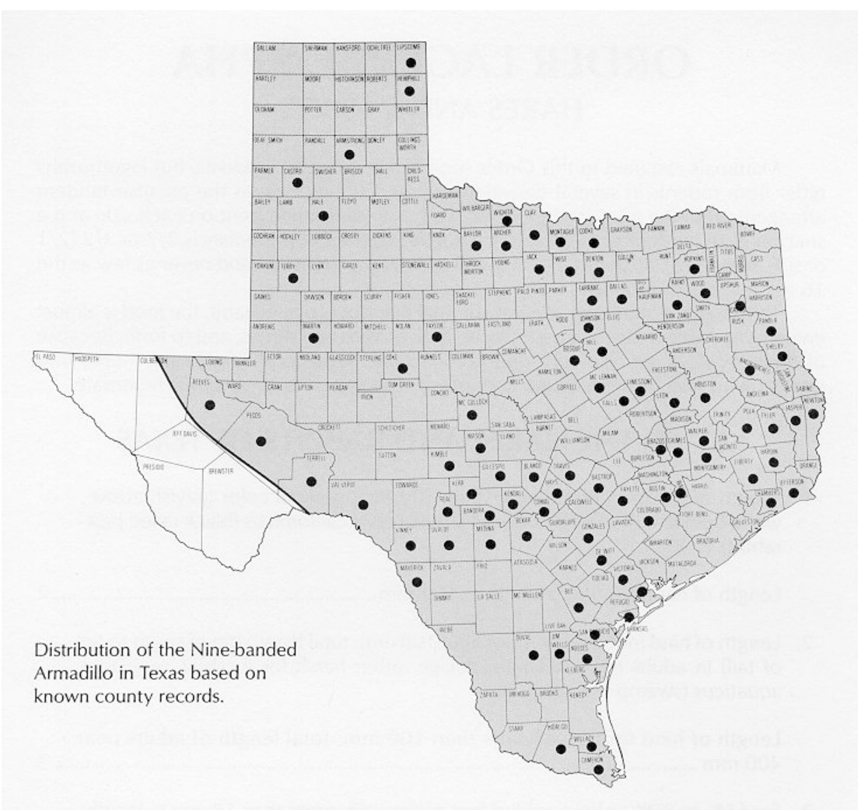
Nine-banded Armadillo

Order Xenarthra : Family Dasypodidae : *Dasypus novemcinctus* (Linnaeus)



Description. About the size of a terrier dog, upperparts encased in a bony carapace with large shields on shoulders and rump and nine bands in between; front feet with four toes, middle two longest; hind foot five-toed, the middle three longest, all provided with large, strong claws; tail long, tapering and completely covered by bony rings; color brownish, the scattered hairs yellowish white. There are 30 or 32 peglike teeth. External measurements average: total length, 760 mm; tail, 345 mm; hind foot, 85 mm. Weight of adult males, 5-8 kg; females, 4-6 kg.

Distribution in Texas. Occurs throughout much of the state; absent from the western Trans-Pecos.



Distribution of the Nine-banded Armadillo in Texas based on known county records.

Habits. Soil texture exerts a definite influence upon the number of armadillos present in a given area. Those soils that are more easily dug, other factors being equal, will support a greater population density. In the sandy soils of Walker County, a population density of about one armadillo to 1 ha is common; in Brazos County, where the soils are more heavily impregnated with clay and become packed during the dry seasons, density averages one to 4 ha. In the rocky terrain of the Edwards Plateau, the animals tend to concentrate in the alluvial stream bottoms and den in the cracks and crevices of the numerous limestone outcroppings in that area. In the blackland section of Texas, where the soils are heavy clays, the animals are extremely rare and restricted to the vicinity of streams where they can burrow into the banks and probe for food in the relatively soft soils near water. Perhaps the most important factor contributing to the distribution of armadillos is the hardness of the soil during the dry season, because the food of the animal is obtained largely by probing for insects and other forms of animal life in the ground.

Armadillos are fond of water; where climatic conditions tend to be arid, the animals concentrate in the vicinity of streams and water holes. Tracks in the mud around small ponds give evidence that the armadillos visit them not only for purposes of drinking and feeding, but also to take mud baths. Excess water, however, has a limiting effect on them because they avoid marshy areas.

Few animals of comparable size have so many dens per individual as the armadillo. The length, depth, and frequency of occurrence of their burrows depend somewhat upon soil conditions. In sandy areas the animals are extremely active diggers; in addition to numerous occupied burrows, one finds many that have been abandoned or are used only occasionally as shelters. In central Texas, the majority of their dens are along creek banks whereas in the sandy soils of eastern Texas they are found almost everywhere. On the coastal prairies the sandy knolls are especially sought as den sites more because of protection from floods than because of ease of digging. In the Edwards Plateau natural caves, cracks, and crevices among the limestone outcroppings afford abundant shelter; excavated burrows are few in number and usually shallow.

Dens vary from 1 to 5 m in length and from a few centimeters below the surface to a depth of 1.3 m. Averaging between 17 and 20 cm in diameter, their plan is usually simple, with few turns except those caused by obstacles such as roots, rocks, and so forth. Many of the shallow burrows serve as food traps in which insects and other invertebrates take refuge and to which the armadillo goes on his foraging excursions. Burrows that are used for breeding purposes usually have a large nest chamber 45 cm or more in diameter and containing the rather loosely constructed nest of dried leaves, grasses, and other plant items. These materials are merely stuffed into the chamber and the animal pushes its way in and out each time the nest is used. Usually, each occupied burrow is inhabited by only one adult armadillo.

Because of their almost complete lack of hairy covering, armadillos are easily affected by climatic conditions. In the summer season they are more active in the cool of the evening and at night, but in midwinter their daily activities are reversed and the animals become active during the warmest part of the day, usually in mid-afternoon. They do not hibernate nor are they equipped to wait out long periods of inclement weather. Long periods of freezing weather effectively eliminate armadillos from an area.

Of special interest is the behavior of this animal in the water. Its specific gravity is high and the animal normally rides low in the water when swimming. Apparently, it tires easily when forced to swim for any distance. If the stream to be crossed is not wide, the armadillo may enter on one side, walk across the bottom, and emerge on the other side. If the expanse of water to be traversed is of considerable extent, the animals ingest air, inflate themselves, and thus increase their buoyancy. The physiological mechanism by which the armadillo can ingest air and retain it in its digestive tract to increase buoyancy is not known, but it appears to be under voluntary control.

Many legends have arisen concerning the food habits of armadillos. Among the rural folks in the South they are commonly called "gravediggers" and are thought to dig into human graves and dine upon the contents. Also, they have quite a reputation as a depredator of quail, chicken, and turkey eggs. A study of their food habits by examination of more than 800 stomachs revealed that no fewer than 488 different food items are eaten. Ninety-three percent (by volume) of their food is animal matter, chiefly insects and other invertebrates. Among the insects, nearly 28% were larval and adult scarab beetles — forms that are highly destructive to crops and pastures; termites and ants comprised about 14%; caterpillars nearly 8%; earthworms, millipedes, centipedes, and crayfish appeared conspicuously in their diet at times. Reptiles and amphibians comprised only a small part of their diet; these were captured usually during periods of cold weather. Birds' eggs were found in only 5 of 281 stomachs.

Observations by field workers strongly indicate that the armadillo, which usually leaves conspicuous signs of its presence, often is accused of the destruction of quail and chicken nests when the culprit is actually some other animal. More than two-thirds of the slightly less than 7% of vegetable matter in the diet was material ingested with other food items and represents nothing of economic importance. Berries and fungi made up 2.1% of the entire diet. Reports indicate that at times the armadillo may feed on such fruits as tomatoes and melons but the amount of damage done to these crops is relatively small. Carrion is readily eaten when available, and dead carcasses of animals frequently are visited not only for the carrion present but also for the maggots and pupae of flies found on or near them.

Reproduction in the nine-banded armadillo is marked by two distinct and apparently unrelated phenomena: the long period of arrested development of the blastocyst prior to implantation (delayed implantation), and the phenomenon of specific polyembryony, which results in the normal formation of identical quadruplets. In normal years about half of the females become pregnant by the end of July, which is the beginning of the breeding season. At 5-7 days the ovum forms a blastocyst and passes into the uterus. At this point development ceases, and the vesicle remains free in the uterus. Here it is constantly bathed in fluids secreted by the glandular lining of the uterus, which supplies enough nutrition and oxygen for survival. Implantation does not occur until November, about 14 weeks after fertilization. During this process, the blastocyst divides into growth centers, each of which very shortly redivides to produce four embryonic growth centers attached by a common placenta to the uterus. Development of each of the embryos then proceeds normally, and the four young are born approximately 4 months later in March, although some females have been noted with new litters as early as February and as late as the latter part of May. Young are born fully formed and with eyes open. Within a few hours they are walking, and they begin to accompany the mother on foraging expeditions within a few weeks. The nursing period is probably less than 2 months, but the young may remain with the mother even after weaning until they are several months old. Normally the young born in one year mature during the winter and mate for the first time in the early summer of the following year.

This phenomenon of delayed implantation may, in part, account for the successful invasion of the armadillo into temperate regions. Without this characteristic of the reproductive cycle, the young would be born at the beginning of winter, when their chance of survival would be greatly reduced. Apparently, the reproductive cycle is easily affected by adverse environmental conditions, particularly drought conditions. This probably is due to the shortage of ground insects or the difficulty of obtaining these in sandy or hard dried soils.

Armadillos are believed to pair for each breeding season, and a male and a female may share a burrow during the season. Because of the bony carapace and ventral position of the genitalia, copulation occurs with the female lying on her back.

Armadillos are frequently utilized as food in parts of Texas and Mexico. The meat is light-colored and when properly cooked is considered by some the equal of pork in flavor and texture.

Remarks. The common occurrence of this species in eastern Texas is a phenomenon that has developed largely since 1900. When Vernon Bailey published his *Biological Survey of Texas* in 1905, he mapped the distributional limits of the armadillo as between the Colorado and Guadalupe rivers with extralimital records from Colorado, Grimes, and Houston counties. By 1914 the armadillo had crossed the Brazos River and moved to the Trinity River, and along the coast had already reached the Louisiana line in Orange County. The northward and eastward range expansions continued over the next forty years, and by 1954 the armadillo was known from everywhere in eastern Texas except Red River and Lamar counties. By 1958 it was known from these latter two counties, and today is abundant everywhere in the region.

Apparently pioneering was most successful in a riparian habitat, and invasion was especially rapid parallel to rivers, which served as dispersal conduits. Average invasion rates have been calculated as from 4 to 10 km per year in the absence of obvious physical or climatic barriers. Possible reasons for the armadillo’s northward expansion since the nineteenth century include progressive climatic changes, encroaching human civilization, overgrazing, and decimation of large carnivores.

Photo credit: John L. Tveten.

Great Trinity Forest Management Plan

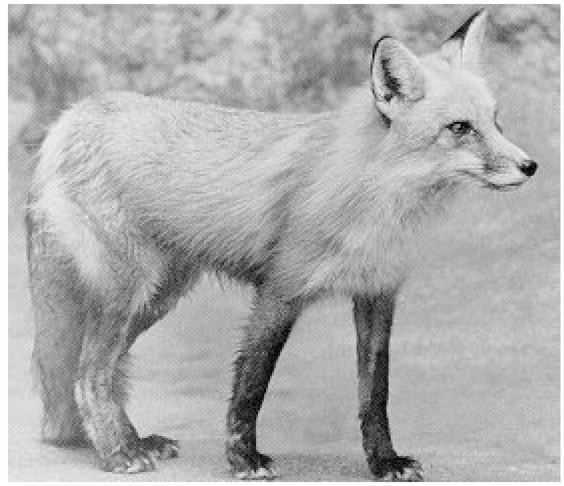
Wildlife Management

Red Fox

(Vulpes vulpes)

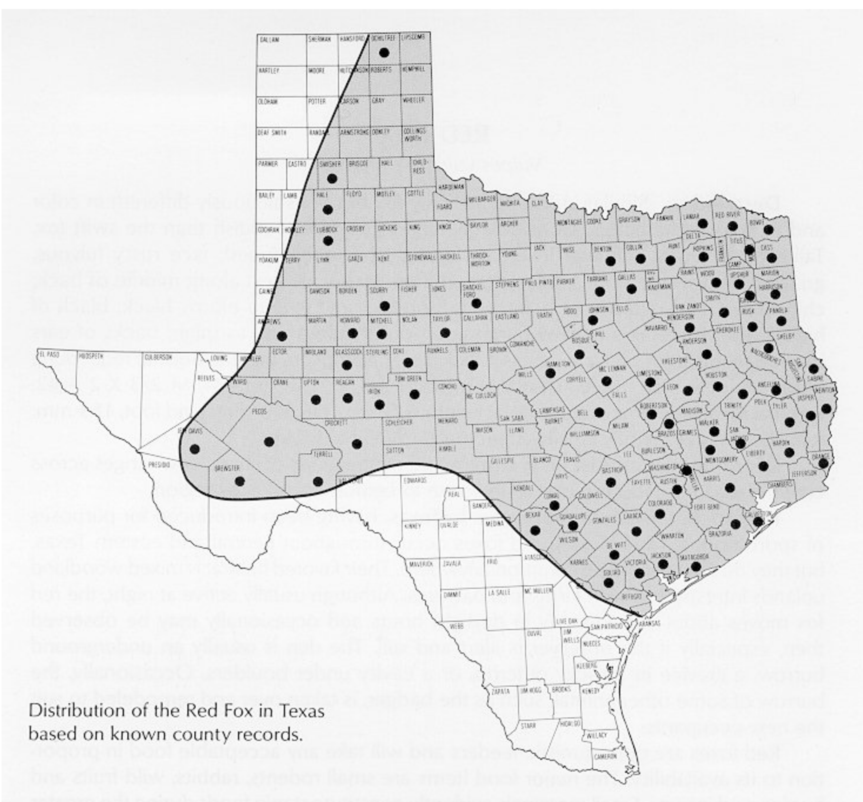
Red Fox*

Order Carnivora : Family Canidae : *Vulpes vulpes* (Linnaeus)



gray fox but conspicuously different in color and in cranial characters. Considerably larger and more reddish than the swift fox. Tail a thick "bush," circular in cross section, and white-tipped; face rusty fulvous, grizzled with white; upperparts bright golden yellow, darkest along middle of back; chin, throat and mid-line of belly white; forefeet and legs to elbow black; black of hind feet extends as a narrow band along outer side of leg to thigh; backs of ears black. Several color phases — cross, black, silver, Sampson, and the normal red. Young duller in color than adults. Dental formula: I 3/3, C 1/1, Pm 4/4, M 2/3 X 2 = 42. External measurements average: total length, 972 mm; tail, 371 mm; hind foot, 163 mm; females average slightly smaller than males. Weight, 3-5 kg.

Distribution in Texas. Introduced in eastern and central parts of state. Now ranges across central Texas from eastern part of the state to central Trans-Pecos region.



Distribution of the Red Fox in Texas based on known county records.

Habits. Red foxes are not native to Texas, having been introduced for purposes of sport around 1895. Today, red foxes occur throughout central and eastern Texas, but they do not seem to be common anywhere. Their favored habitat is mixed woodland uplands interspersed with farms and pastures. Although usually active at night, the red fox moves about considerably in daylight hours and occasionally may be observed then, especially if the observer is alert and still. The den is usually an underground burrow, a crevice in a rocky outcrop, or a cavity under boulders. Occasionally, the burrow of some other animal, such as the badger, is taken over and remodeled to suit the new occupants.

Red foxes are opportunistic feeders and will take any acceptable food in proportion to its availability. The major food items are small rodents, rabbits, wild fruits and berries, and insects. Small mammals evidently constitute staple foods during the greater part of the year. Other kinds of prey fluctuate according to season, weather conditions, abundance, and vulnerability of prey populations, and with the experience of the fox. Young animals learning to hunt have to take what they can get.

Female red foxes have a single estrous each year and reputedly remain mated for life. Males and females pair off and mate from late December to January or February. Females have a very short period of heat that lasts only 2-4 days. The young, which may number anywhere from one to 10 (average, four to six), are born in March or April following a gestation period of about 53 days.

The female establishes the den site for the young in late winter, but both parents live together while raising the young. Foxes either dig their own dens or utilize those of other burrowing animals. Sometimes two litters may occupy one den.

The young at birth are dark brown or black in color, but the tip of the tail is white. They are blind and helpless; the eyes open at the age of 8 or 9 days. They seldom venture out of the den until they are a month old, and the den may also be their refuge for the next 2 months or longer. The parents are solicitous of the pups, bringing them food and guarding the den. The family remains together until autumn, by which time the young have attained almost adult proportions.

Few foxes live beyond the age of 3 or 4 years, particularly in areas where they are hunted and trapped heavily. Man and domestic dogs are their major predators, although pups may be lost to great horned owls and other predators. Red foxes are susceptible to a variety of diseases, including rabies, distemper, and infectious canine hepatitis.

* *nonnative species*

Photo credit: John L. Tveten.

Great Trinity Forest Management Plan

Wildlife Management

Southern Short-tailed Shrew

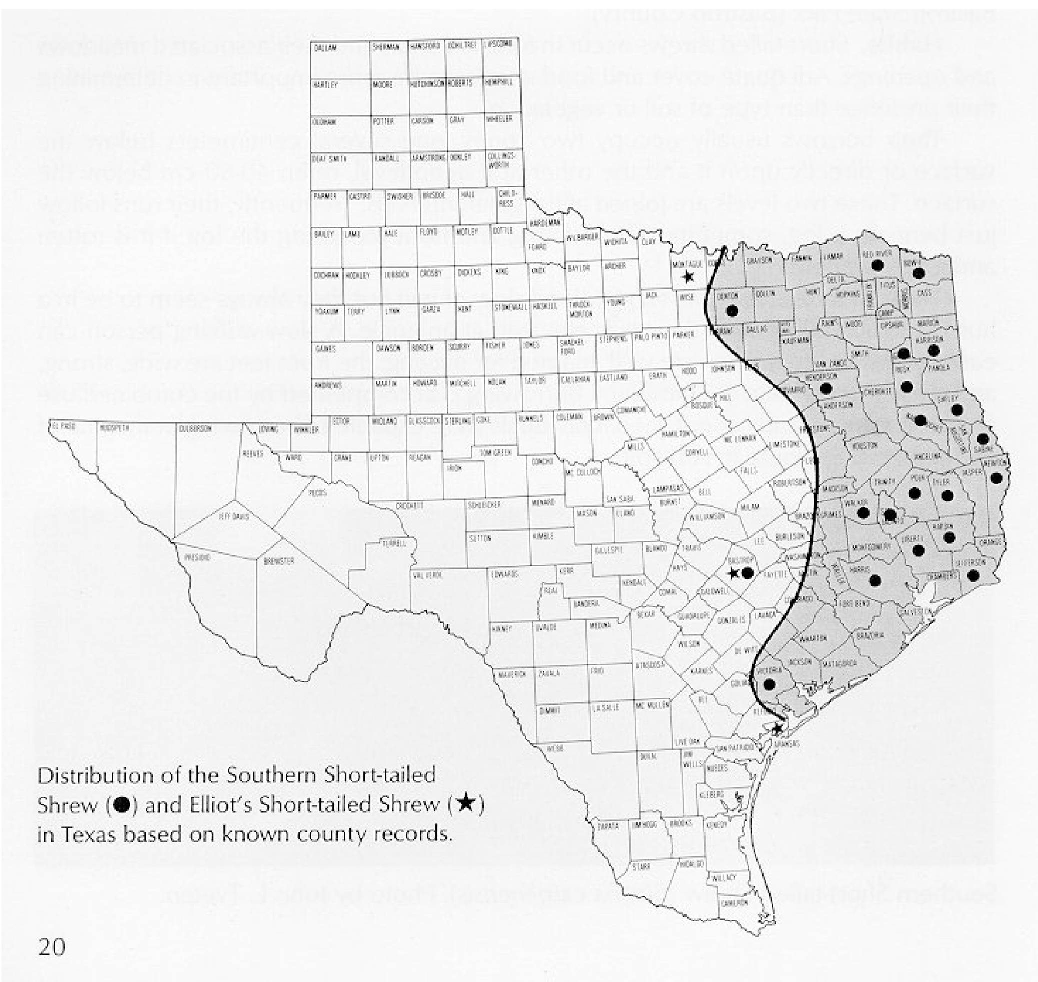
(Blarina carolinensis)

Southern Short-tailed Shrew

Order Insectivora : Family Soricidae :
Blarina carolinensis (Bachman)

Description. A rather robust, short-legged, short-tailed shrew with long, pointed, protruding snout; external ears short and nearly concealed by the soft, dense fur; tail less than half the length of head and body, usually less than twice as long as hind foot; upperparts dark slate to sooty black; underparts paler; tail black above, paler below. Dental formula: I 4/2, C 1/0, Pm 2/1, M 3/3 X 2 = 32. External measurements average: total length, 88 mm; tail, 17 mm; hind foot, 11 mm. Weight, 18-28 g.

Distribution in Texas. Eastern one-fourth of the state with a recent, disjunct record from Bastrop State Park (Bastrop County).



Distribution of the Southern Short-tailed Shrew (●) and Elliot's Short-tailed Shrew (★) in Texas based on known county records.

Habits. Short-tailed shrews occur in forested areas and their associated meadows and openings. Adequate cover and food appear to be more important in determining their presence than type of soil or vegetation.

Their burrows usually occupy two zones, one several centimeters below the surface or directly upon it and the other at a deep level, often 40-60 cm below the surface. These two levels are joined at irregular intervals. Frequently, their runs follow just beneath a log, sometimes penetrating and honeycombing the log if it is rotten and easily worked.

These creatures are short-legged and slow of gait but they always seem to be in a hurry, running along with their tails elevated at an angle. A slow-walking person can easily overtake them. They are well adapted for digging; the front feet are wide, strong, and slightly larger than the hind feet. Burrowing is accomplished by the combined use of forefeet, head, and nose. Timed individuals were capable of burrowing at the rate of about 30 cm a minute in soft soil.

Like the least shrew (*Cryptotis*), *Blarina* seem to be more sociable than long-tailed shrews. Several individuals seem to use a common burrow system and seldom do they fight when two or more are placed in a cage. It appears certain that the male and female remain together during the prebreeding season.

The food habits of these shrews are strangely unshrewlike in that they consume relatively large quantities of vegetable matter (nuts, berries, and so forth). Analyses of more than 400 stomachs from East Texas revealed the following items (expressed in percentages of occurrence): insects 77.6; annelids, 41.8; vegetable matter, 17.1; centipedes, 7.4; arachnids, 6.1; mollusks (mostly snails), 5.4; vertebrates (mice and salamanders), 5.2; crustacea (mostly sowbugs), 3.7; undetermined matter, 2.4. There is considerable evidence that *Blarina* stores snails for winter use.

An interesting feature of this shrew is the poison produced by the submaxillary glands, which is present in the saliva and may be introduced into wounds made by the teeth. Injections of 6 mg of an extract prepared from the submaxillary gland are strong enough to kill mice but there is little likelihood of the venom having any serious effect on man.

The breeding season of *Blarina* extends from February through September. There appear to be two and possibly three litters of five to seven young produced in this period. The gestation period is probably between 21 and 30 days. The young are pink, blind, and helpless at birth, and they weigh slightly more than 1 g. They are relatively slow in developing; the eyes of young born in captivity were still closed on the 22nd day. The young are born in a special nest of grasses and other dry vegetation under a rotten log or stump or under the ground. In each instance entrance to it is gained by way of an underground tunnel. These nests are much larger than the more commonly found "resting" nests. Records indicate that very few of these shrews attain an age of 2 years.

Since the reproductive potential is high in this shrew, one can assume that its natural enemies are many. Known predators include the milk snake, black snake, red-tailed hawk, red-shouldered hawk, sparrow hawk, broadwinged hawk, barn owl, short-eared owl, barred owl, horned owl, long-eared owl, screech owl, fox, weasel, and skunk. Doubtless, others could be added to the list.

Photo credit: John L. Tveten.

Great Trinity Forest Management Plan

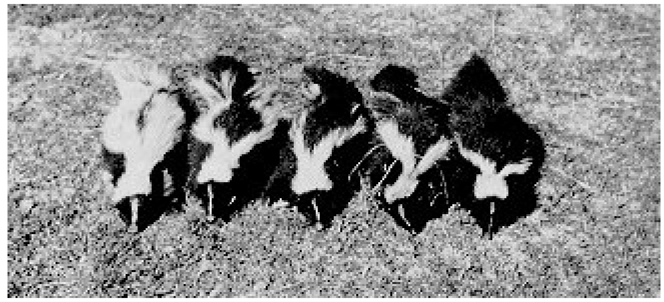
Wildlife Management

Striped Skunk

(Mephitis mephitis)

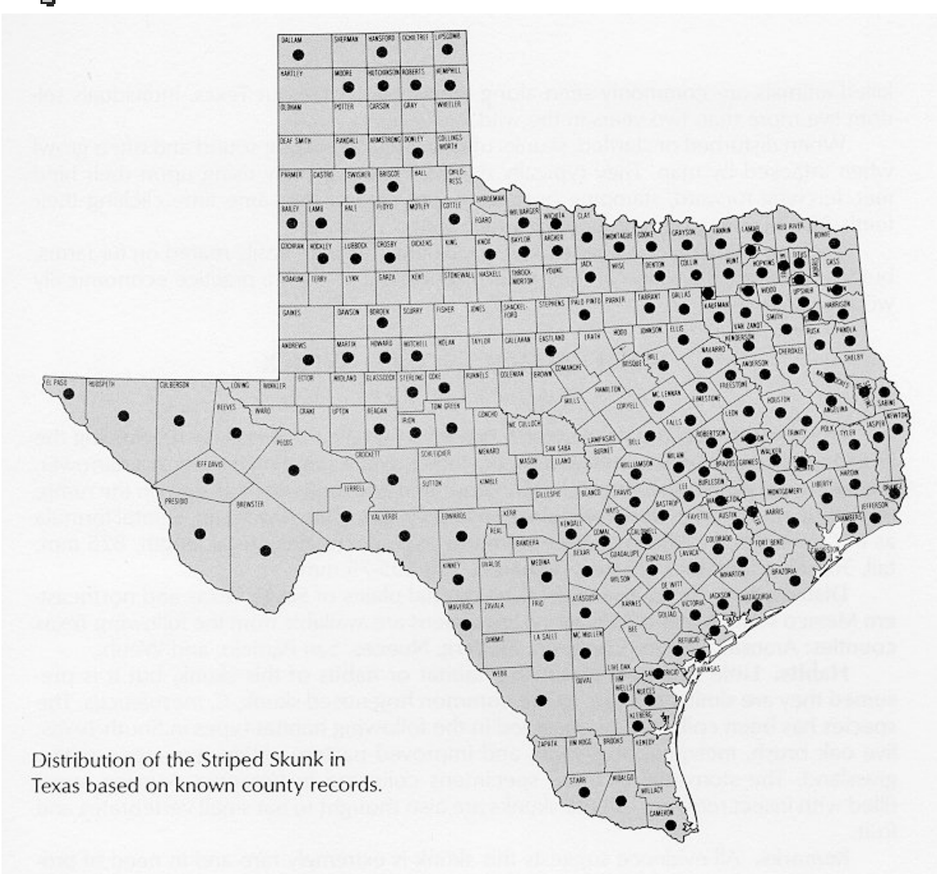
Striped Skunk

Order Carnivora : Family Mustelidae :
Mephitis mephitis (Schreber)



Description. A medium-sized, stout-bodied skunk with two white stripes on sides of back that join each other in the neck region and extend onto the head anteriorly and onto each side of the tail posteriorly (note varying patterns in photo at right); tip of tail black; two large scent glands, one on each side of the anus, produce the characteristic skunk musk; ears short, rounded; eyes small; five toes on each foot, front ones armed with long claws; hind feet with heel almost in contact with ground; tail long and bushy; pelage long, coarse and oily. Dental formula as in the spotted skunk. Sexes colored alike, but males usually larger than females. External measurements average: (males), total length, 680 mm; tail, 250 mm; hind foot, 90 mm; (females), 610-225-65 mm. Weight, 1.4-6.6 kg, depending on age and amount of fat.

Distribution in Texas. Statewide.



Distribution of the Striped Skunk in Texas based on known county records.

Habits. Striped skunks are inhabitants of wooded or brushy areas and their associated farmlands. Rocky defiles and outcrops are favored refuge sites, but when these are absent the skunks seek out the burrows of armadillos, foxes, and other animals. In central Texas, favored refuge sites are under large boulders.

These skunks are largely nocturnal and seldom venture forth until late in the day; they retire to their hideouts early in the morning. One of us (Davis) has seen striped skunks abroad in midday only twice, and in each instance a female was trailing her family of third-grown youngsters in single file across a meadow to a patch of woodland beyond.

In late fall they become exceedingly fat. In Texas, they are abroad throughout the year and seemingly more active in winter than in the heat of summer. They are social creatures; often several individuals occupy a well-situated winter den. J.D. Bankston of Mason, Texas informed us that he removed as many as seven striped skunks from one winter den and that one of his neighbors found 10 in one den in December. These may have constituted family groups.

Striped skunks are not choosy in their food habits. In Texas, their seasonal food, as judged from the analyses of 79 viscera, is as follows (expressed in percentages): Fall — insects, 76; arachnids, 24. Winter — insects, 52.3; arachnids, 5.3; reptiles, 1.6; small mammals, 18.3; vegetation, 22; birds and millipedes making up the balance. Spring — insects, 96; reptiles, 1.6; small mammals, 2; vegetation and small birds making up the balance. Summer — insects, 88; arachnids, 4; reptiles, 1.5; small birds, 3.5; centipedes, small mammals, and vegetation making up the balance.

Breeding begins in February or March. After a gestation period of about 63 days, the three to seven (average, five) young are born. In Texas, most of the young appear in the first half of May. There is some evidence that two litters may be born to certain females, but one litter seems to be the general rule. The nursery is a cavity under a rock, a burrow, or a thicket of cactus or other protective vegetation. Usually the mother builds a nest of dried grasses and weed stems for the blind, helpless young. The young remain in the nest until their eyes are open and they are strong enough to follow their mother.

Striped skunks have few natural enemies. Owl, hawks, coyotes, bobcats, foxes, and dogs may occasionally take one, but most predators are repulsed by the odor of their musk. Striped skunks are highly susceptible to being struck by vehicles, and road-killed animals are commonly seen along highways throughout Texas. Individuals seldom live more than two years in the wild.

When disturbed or startled, skunks utter a peculiar purring sound and often growl when attacked by man. They typically express their anger by rising upon their hind feet, lurching forward, stamping both front feet, and at the same time clicking their teeth. The expelling of musk generally follows this behavior.

Their fur is the most valuable of all the skunks. They are easily reared on fur farms, but the relatively low value of their pelts does not make such a practice economically worthwhile.

Photo credit: D. W. Lay.

Great Trinity Forest Management Plan

Wildlife Management

Swamp Rabbit

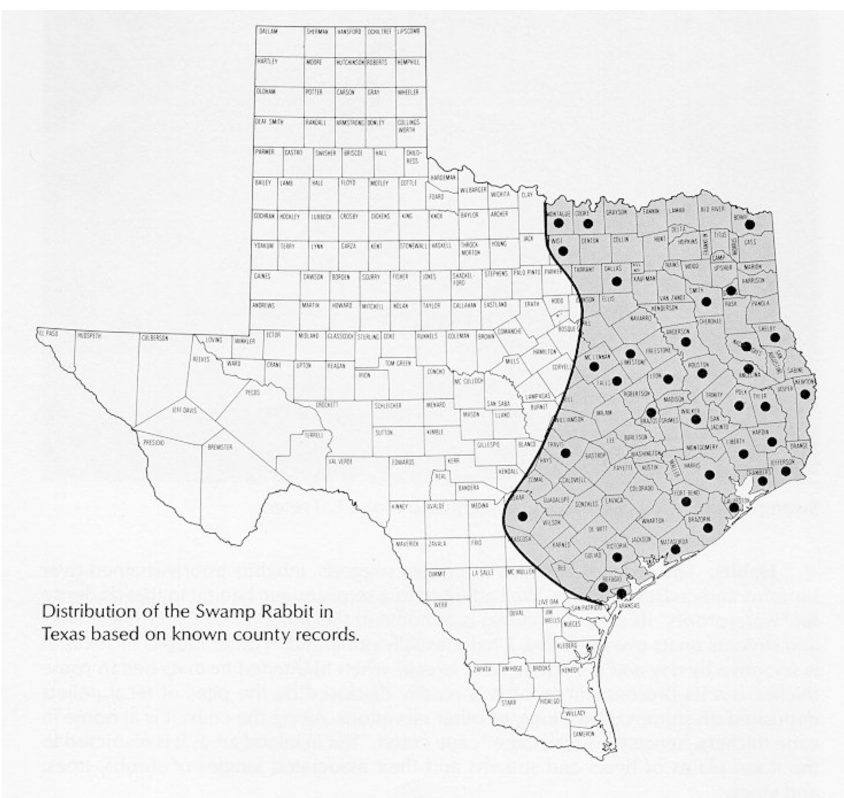
(Sylvilagus aquaticus)

Swamp Rabbit

[Order Lagomorpha] : Family Leporidae : *Sylvilagus aquaticus* (Bachman)

Description. Largest of the "cottontails" within its range; pelage coarse and short for a rabbit; upper parts grayish brown, heavily lined with blackish; rump, upperside of tail, and back of hind legs dull ochraceous brown; sides of head and body paler than back, less suffused with blackish; underparts, including underside of tail, white except for buffy underside of neck; front legs and tops of hind feet cinnamon rufous. External measurements average: total length, 534 mm; tail, 69 mm; hind foot, 106 mm; ear, 70 mm. Weight, 1.5-3 kg.

Distribution in Texas. Found in eastern one-third of state west to Montague, Wise, and Bexar counties.



Distribution of the Swamp Rabbit in Texas based on known county records.

Habits. The swamp rabbit, as the name suggests, inhabits poorly drained river bottoms and coastal marshes. Well adapted to a semi-aquatic habitat in that its dense fur "waterproofs" its skin, the animal is at home in the water. In fact, it crosses rivers and streams on its own initiative, a habit usually not found in other rabbits in Texas. It is secretive by day and is seldom seen, except when frightened from its bed in some thicket, but its presence in an area is readily disclosed by the piles of fecal pellets deposited on stumps, down logs, or other elevations. Along the coast it is at home in cane thickets, hence the local name "cane cutter," but in inland areas it is restricted to the flood plains of rivers and streams and their associated tangles of shrubs, trees, and vines.

In southeast Texas, one swamp rabbit per 2.8 ha of poorly drained bottomland is typical. The rabbits frequent a definite local range, which they refuse to leave even when pursued by dogs. Their chief protection are thickets of briars or brush, rather than underground burrows. In this area both eastern cottontails (*S. floridanus*) and swamp rabbits occupy the creek and river bottoms in about equal numbers, but in the uplands only cottontails are found.

Little is known of their food habits although succulent vegetation including grasses, forbs, and the new shoots of shrubs are probably important.

The breeding season extends at least from January to September, but the peak is in February and March when green vegetation is available. Possibly two or more litters of two to three young are reared annually. After a gestation period of 39-40 days, the young are born in, or transferred to, surface nests composed of vegetation and lined with rabbit fur, or nests in holes in logs and stumps. A nest found at the base of a cypress stump was composed of Spanish moss and rabbit fur; it held six small rabbits. Another found under a long, fallen branch of a tree was lined with fur and held two young rabbits. At birth the young are covered with fur, but the eyes and ears are closed. This condition is not true of other cottontails. The eyes open and the young rabbit is able to walk in 2 or 3 days.

Among their known natural enemies are gray fox, horned owl, and alligator. Doubtless, they are preyed upon by many other species. Other than man, their chief enemy is floods.

Photo credit: John L. Tveten.

Great Trinity Forest Management Plan

Wildlife Management

Virginia Opossum

(Didelphis virginiana)

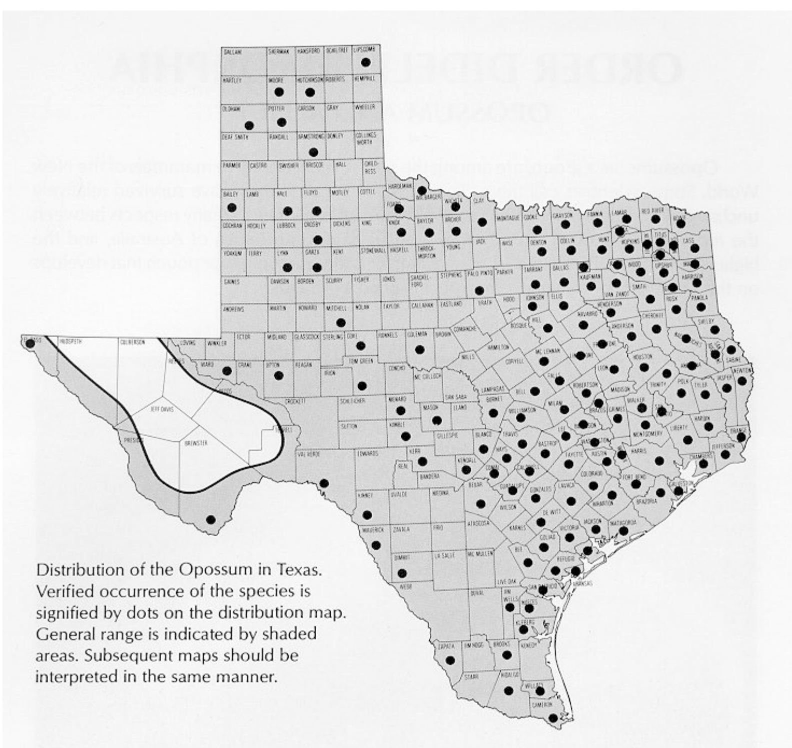
Virginia Opossum

Order Didelphimoria : Family Didelphidae : *Didelphis virginiana* Kerr

Description. A mammal about the size of a terrier dog, with long, scaly, prehensile tail; short, black, leathery ears; long, slender snout; five toes on each foot, the "big toe" on hind foot lacking a claw, thumblike and opposable; soles naked; pouch for young developed during breeding season on abdomen of female; pelage of long guard hairs and short soft underfur; two color phases — (1) grayish and (2) blackish; basal fourth or more of tail black, terminal section whitish; legs and feet blackish, toes often white or whitish. Dental formula: I 5/4, C 1/1, Pm 3/3, M 4/4 X 2 = 50. External measurements of males average: total length, 782 mm; tail, 324 mm; hind foot, 66 mm; of females, 710-320-63.

Weight, 1.8-4.5 kg; males are usually larger and heavier than females.

Distribution in Texas. Occurs statewide except for xeric areas of the Trans-Pecos and Llano Estacado of the Panhandle.



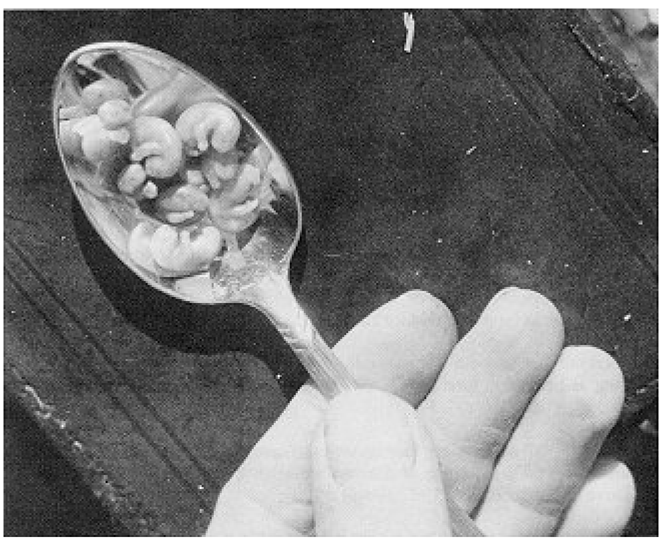
Distribution of the Opossum in Texas. Verified occurrence of the species is signified by dots on the distribution map. General range is indicated by shaded areas. Subsequent maps should be interpreted in the same manner.

Habits. Opossums are primarily inhabitants of deciduous woodlands but are often found in prairies, marshes, and farmlands. In the western part of their native range they generally keep to the woody vegetation along streams and rivers, a habit which permits them to penetrate the otherwise treeless grasslands and deserts of west Texas.

Hollow trees and logs are preferred sites, but opossums will den in woodpiles, rock piles, crevices in cliffs, under buildings, in attics, and in underground burrows. Since they are not adept at digging burrows for themselves they make use of those excavated by other mammals.

Movements of opossums monitored in East Texas showed that these animals typically frequent a home range approximately 4.6 ha in size, although the minimum size of home ranges may vary from 0.12 ha to 23.4 ha. Home ranges tend to overlap considerably. In East Texas woodland habitat the density of opossums is about one opossum every 1.6 ha while in sandy, coastal parts of the state the density is about one opossum every 6 ha.

The opossum is more or less solitary and strictly nocturnal, venturing forth to feed shortly after dark. It feeds on a variety of foods, including rats, mice, young rabbits, birds, insects, crustaceans, frogs, fruits, and vegetables. Analyses of six stomachs from winter-trapped opossums in Texas revealed that the following foods (expressed in percentages) had been eaten: insects (grasshoppers, crickets, beetles, bugs, ants), 62.8; mammals (cottontails), 19.5; birds (sparrow family), 15.5; reptiles (lizards and snakes), 1.0; mollusks (snails), 1.0; crustacea (crayfish), 0.2. In June the food for four opossums was about the same except that fruits and berries were added and birds were lacking.



Their mating season extends from January or February to June or July. Females, which are in heat for about 30 days, breed the first season following birth. The mating period is not longer than 36 hours and terminates with copulation, which is done in a manner similar to dogs. Young opossums have been observed as early as January 24 and as late as August 15. Usually two litters are produced — in February and June. The young, five to 21 in number, are born after a gestation of 11-12 days and each weighs about 3 grains (1/5 of a gram; 1/2,380 of a pound)! Blind, nearly helpless, hardly larger than honey bees, and embryonic in appearance they crawl unaided into the abdominal pouch of the mother, each attaching itself to a nipple. Shortly after a young one begins to nurse, the nipple swells and completely fills its mouth, thereby firmly attaching it to its mother. It remains attached until it is about 7 weeks of age, at which time it has grown large enough to detach itself. This peculiar adaptation compensates in part for the brief period of uterine development and assumes part of the function performed by the placenta in higher mammals. Since the number of teats is seldom more than 13, young born in excess of that number are doomed to die.

Mortality is high during the first year of life, and population turnover is relatively rapid. Known predators include foxes, coyotes, horned owls, and barred owls. Opossums are commonly seen killed on highways. The normal lifespan may be as low as 2 years.

The opossum is the second most commonly harvested furbearing animal in Texas, but the value of its pelt is low. During the period 1976 to 1982 the average value of an opossum pelt was only $1.83. Many trappers do not consider opossums worth "skinning out." Their fur is used primarily for trim on less expensive coats and hats.

Photo credits: John L. Tveten (top), John Wood (bottom).

Great Trinity Forest Management Plan

Wildlife Management

White-footed Mouse

(Peromyscus leucopus)

White-footed Mouse

Order Rodentia : Family Muridae : *Peromyscus leucopus* (Rafinesque)

Description. A medium-sized, short-tailed, white-footed mouse; tail about 43% of total length, sparsely haired, darker above than below but usually not sharply bicolor; upperparts cinnamon rufous mixed with blackish; sides paler, with less admixture of black; underparts and feet white, the "ankle" slightly brownish. External measurements average: total length, 173 mm; tail, 78 mm; hind foot, 21 mm. Weight, 18-32 g, averaging about 22 g. Most easily confused with *P. gossypinus* and *P. maniculatus*; *P. leucopus* differs from the former in smaller size, shorter body, lighter weight, and brighter colors; from the latter in less hairy and not sharply bicolor tail, usually shorter pelage, and lack of whitish tufts at base of ears.

Distribution in Texas. Statewide.

Habits. In the main, these mice are woodland dwellers, a fact that is best illustrated along the western border of their range where they are restricted almost entirely to creek and river bottoms. As one progresses eastward, the mice are found in a progressively greater variety of habitats. In east-central Texas, they are most abundant in bottom lands, less so in post oak uplands and almost completely absent from prairie lands. They are adept at climbing and often den in hollow trees out of danger from overflow waters. In areas not subject to inundation, they live in dens under logs, in stumps, brush piles, burrows, or buildings.

In much of its range, this mouse is one of the commonest of small mammals. In Brazos County, the population of this mouse is exceeded only by that of the cotton rat. In 3,483 trap-nights, 161 cotton rats and 121 white-footed mice were captured; a ratio, respectively, of 21.6 and 28.7 trap-nights per animal. The maximum home range of adult males is about 0.2 ha, that of adult females about 0.15 ha. The mice seldom travel more than 50 m once they are established in suitable quarters. The dispersal of the population generally is accomplished by movements of the unestablished young mice.

The food of white-footed mice is varied, but their chief reliance is seeds and such nuts as acorns and pecans. When food is abundant, they store it in and about their nests for winter use. Caches of "several quarts" have been reported. Like squirrels, these mice have internal cheek pouches in which they can place food for transport to caches. In spring and summer they feed to some extent on fruits and on insects, snails, and other invertebrates.

In east-central Texas, gravid females have been captured in nearly every month of the year. Litter size varies from one to six, averaging about four. Captive females have produced as many as 10 litters and 45 offspring in 1 year, but in the wild the number of litters appears to be four or five. The gestation period is from 22 to 25 days in nonlactating females and 23 to 37 days in those that are lactating. At birth the young are blind, pink, and weigh about 2 g. They become pigmented dorsally in the first 24 hours, their eyes open in about 13 days, and they are weaned at the age of 22 or 23 days if the mother is expecting a new family; if otherwise, they may nurse as long as 37 days. Young females mature sexually at the age of 10 or 11 weeks and may bear their first litters at the age of 13 or 14 weeks. Usually, females born in the spring rear one or two litters themselves before winter sets in. They seldom live to be more than 18 months old in the wild.

Where numerous in an area, they can become destructive of stored and shocked grains and consequently need to be controlled. But in most places they are of little or no economic significance if such natural predators as owls, snakes, and weasels are not destroyed.

Photo credit: John L. Tveten, courtesy of Texas A&M University Press.

Great Trinity Forest Management Plan

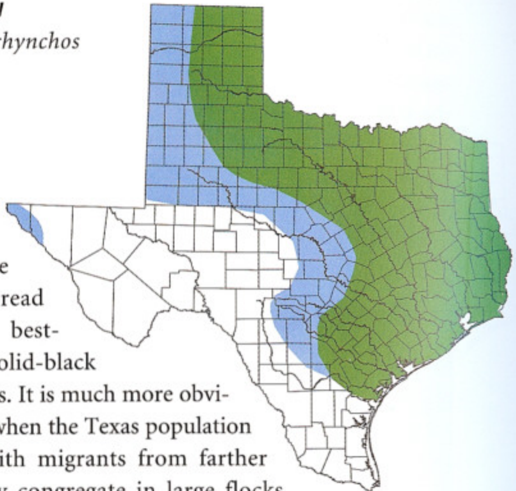
Wildlife Management

American Crow

(Corvas brachyrhynchos)

AMERICAN CROW

Corvus brachyrhynchos



BACKGROUND This crow is the most widespread and probably best-known of the solid-black corvids in Texas. It is much more obvious in winter, when the Texas population is bolstered with migrants from farther north and they congregate in large flocks. American Crows often form large communal roosts, sometimes numbering in the thousands. Young birds do not reach maturity until they are at least two years old, and most do not breed until they are at least four. Young from previous broods sometimes remain with their parents and help with the next year's nesting attempt.

IDENTIFICATION The American Crow is glossy black with a slightly rounded tail.

SIMILAR SPECIES The ranges of three other solid-black corvids overlap with the American Crow in Texas. The Fish Crow (*C. ossifragus*) is the most similar, but it is smaller and its voice is more nasal (usually heard as a double call). The Fish Crow occurs primarily along the Sabine River and the eastern half of the Red River in Texas. The Common Raven (*C. corax*) overlaps with the American Crow in winter on the eastern Edwards Plateau. Larger than crows, it has a wedge-shaped tail, a much heavier bill, shaggy throat feathers, and a deeper and rougher voice. In flight, the primaries of the Common Raven are more distinct and fingerlike, and the tail shape is more readily apparent. The Chihuahuan Raven (*C. cryptoleucus*) is found more commonly with American Crows than the previous species, and it is about the same size. This raven, however, has a wedge-shaped tail, a slightly heavier bill, and a distinctive voice.

HABITAT Very adaptable to a wide range of habitats. Requires open areas for feeding, with scattered trees for nesting and roosting, so the primary habitat type where this species is *not* found is closed-canopy forest. Frequently found in man-made habitats such as agricultural lands, city parks, golf courses, and other urban environments.

American Crow. Photo by Mark W. Lockwood.

STATUS AND DISTRIBUTION Common to abundant resident in the eastern half of the state west to the central Panhandle and to the eastern edge of the Edwards Plateau. Rare to locally uncommon migrant and winter visitor farther west, including the remainder of the High Plains, western Rolling Plains, eastern Edwards Plateau, and eastern parts of the South Texas Brush Country. Also a common to uncommon and local winter visitor in the El Paso area.

<u>Great Trinity Forest Management Plan</u>

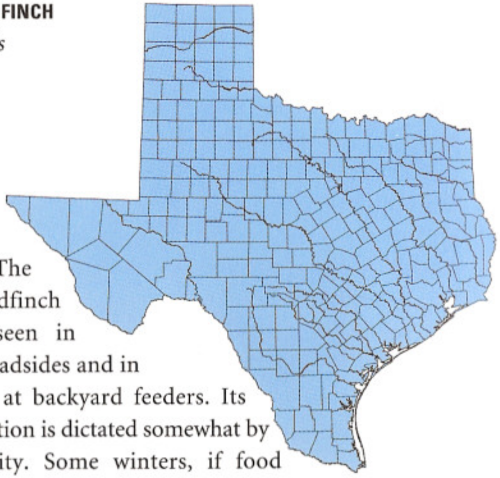
Wildlife Management

American Goldfinch

(<u>Cerduelis</u> <u>tristis</u>)

AMERICAN GOLDFINCH

Carduelis tristis



BACKGROUND The American Goldfinch is normally seen in Texas along roadsides and in hedgerows or at backyard feeders. Its winter distribution is dictated somewhat by food availability. Some winters, if food resources are good farther north, most birds do not reach the state. In other years, feeding stations may be overwhelmed by large numbers of goldfinches. Adult males can usually be identified by their brighter plumage and blacker wings. American Goldfinches are normally seen in flocks, sometimes in fairly large numbers. These social birds are rarely encountered singly. Like all species in the genus, they have an undulating flight. They beat their wings a few times to maintain speed, and this also gives the bird some uplift. The wings are then closed, causing the bird to lose altitude.

IDENTIFICATION Birds in winter plumage are olive-brown above and grayish white below, with white undertail coverts. The face is yellow, being brightest in males. The wings are dark, with two wing bars in females and immature birds. Adult males have black wings with yellow shoulders and a single wing bar. The tail is also dark, with a white tip to the inner webbings of the outer rectrices. Males in breeding plumage are bright yellow with a black cap, wings, and tail. The undertail coverts remain white. Females in breeding plumage are less brilliant yellow and lack the black cap.

SIMILAR SPECIES Winter plumage is similar to the female Lesser Goldfinch (*C. psaltria*), which is yellowish green overall, in contrast to the browner color of the American. The American has a white patch at the base of the tail, rather than the entire inner webbing of the outermost tail feathers of a Lesser Goldfinch. The undertail coverts of the Lesser Goldfinch are yellow. The Pine Siskin (*C. pinus*) can be identified by the heavy streaking on the underparts. It also has patches of yellow, rather than white, in the wings and tail.

HABITAT Along roadsides, in old fields, hedgerows, riparian corridors, open woodlands, and urban areas.

STATUS AND DISTRIBUTION Uncommon to abundant winter resident throughout the state. Occurrence is somewhat irregular, with considerable fluctuation in the number of birds present in a given area from one year to the next. Generally arrives in Texas in late September and departs by mid-May, but may linger into late May and even early June. Very rare summer resident in northeast Texas and in the northeast Panhandle.

American Goldfinch, winter plumage. Photo by Greg W. Lasley.

Great Trinity Forest Management Plan

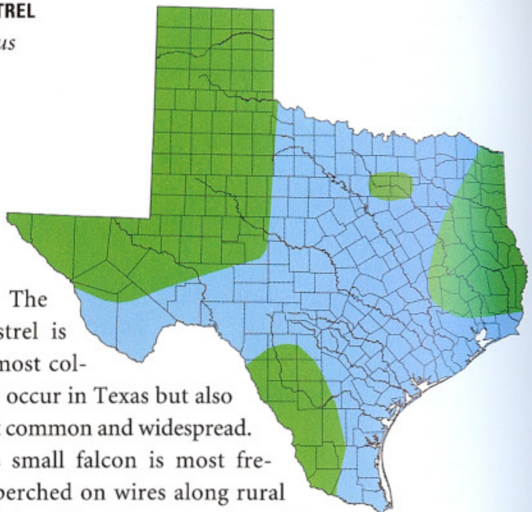
Wildlife Management

American Kestrel

(Falco sparverius)

AMERICAN KESTREL

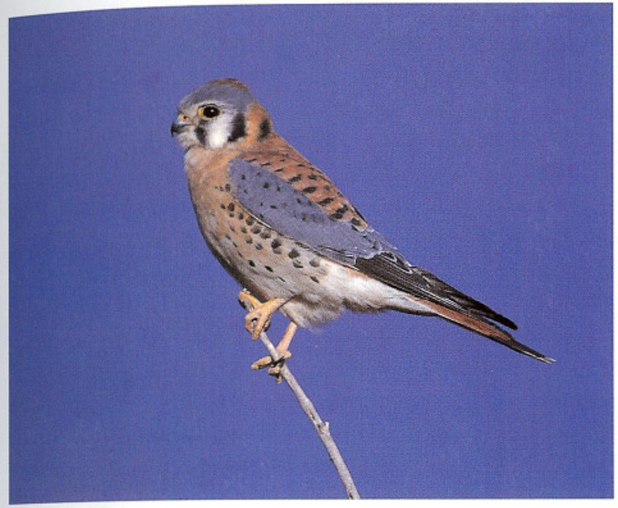
Falco sparverius



BACKGROUND The American Kestrel is not only the most colorful falcon to occur in Texas but also by far the most common and widespread. Although this small falcon is most frequently seen perched on wires along rural roads, it is also found in urban areas throughout the state. Female kestrels migrate earlier than the males, and it appears that in some areas they set up foraging territories in the prime locations, sometimes forcing the later-arriving males into areas with more trees. These small falcons prey on a wide variety of organisms, ranging from large insects to small rodents and birds.

IDENTIFICATION Very colorful and distinctive, the male has a rusty back that is framed by slaty-blue wings. The tail is rufous with a broad black subterminal band with a white tip. The underparts are pale buff to orangish with black spotting on the flanks and belly. The crown is blue-gray with a small rufous crown patch. The face is white with two black stripes, one through the eye and the other behind the auriculars. The female has rusty upperparts, including the wings. The tail is also rusty, but differs from the male in being much duller and having narrow black bars above the subterminal black band. The face and crown are similar to the male, but not as bright or crisp. The underparts of the female are generally white or washed with buff and heavily streaked with brown.

SIMILAR SPECIES The Merlin (*F. columbarius*) is the only other



American Kestrel, male. Photo by Greg W. Lasley.

small falcon found in Texas. It is easily distinguished from the American Kestrel by the uniform blue-gray (male) or brown (female) upperparts and less distinctive facial pattern. The Peregrine falcon (*F. peregrinus*) and Prairie Falcon (*F. mexicanus*) are considerably larger and more uniform in plumage pattern. In general, American Kestrels are much paler below than other species of falcons found in Texas.

HABITAT Found along borders of woodlands, farmlands, open habitats with scattered trees, and grasslands. The breeding population in the Pineywoods is found in open longleaf forests. They also use urban habitats.

STATUS AND DISTRIBUTION Common to abundant migrant and winter resident throughout the state. Uncommon summer resident in the High Plains and Trans-Pecos. Also rare to uncommon summer resident in the Pineywoods, locally in north-central Texas, and the western South Texas Brush Country. There are isolated breeding records for other areas, but these small falcons are generally absent from the remainder of Texas during the summer.

Great Trinity Forest Management Plan

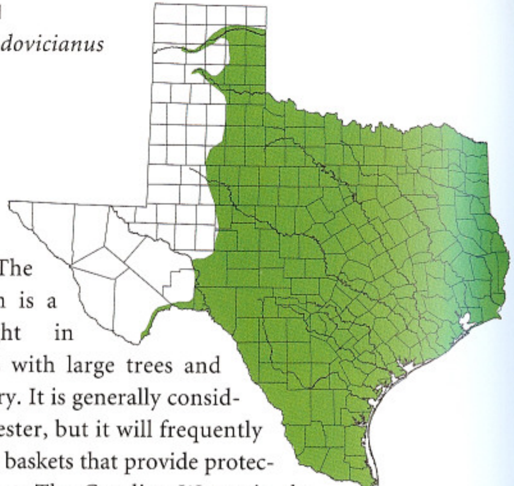
Wildlife Management

Carolina Wren

(Thryothorus ludovicianus)

CAROLINA WREN

Thryothorus ludovicianus



BACKGROUND The Carolina Wren is a common sight in urban habitats with large trees and some understory. It is generally considered a cavity nester, but it will frequently nest in hanging baskets that provide protection for the nest. The Carolina Wrens in the southern half of the South Texas Brush Country and the Lower Rio Grande Valley are classified as a separate subspecies. They are smaller and less rufous in coloration, but they have a slightly larger bill. In the 1960s, it was feared that they were on the way to extirpation, but now they appear to have made a remarkable comeback. The Carolina Wren is the northernmost member of a genus of tropical wrens. Unlike most members of this genus, only the male Carolina Wren sings. In the majority of the other species, both sexes sing slightly different songs in duets.

IDENTIFICATION This medium-sized wren is larger than most of the other wrens found in Texas. The upperparts are deep rusty brown, and the underparts are washed with cinnamon and are not barred. The wings and tail are barred with black, and there are some white markings on the wings. The throat is white, and the sides of the face are mottled with gray. There is also a prominent white eye stripe.

SIMILAR SPECIES The Carolina Wren's range overlaps considerably with that of Bewick's Wren (*Thryomanes bewickii*). Bewick's Wrens found in the western two-thirds of the state are considerably grayer and lack the rusty color so prominent on

the underparts of the Carolina Wren. Bewick's Wrens also have much longer tails that are tipped in white. There are Bewick's Wrens that have more rufous tones to their plumage present during winter in the eastern third of the state. These birds still lack the rufous tones characteristic of a Carolina Wren.

HABITAT Found in a variety of mostly woodland habitats. Most common in mesic woodlands with a patchy deciduous understory. Common in riparian corridors throughout their range in Texas.

Carolina Wren. Photo by Greg W. Lasley.

STATUS AND DISTRIBUTION Common to abundant resident in the eastern two-thirds of the state. Along the western edge of the range, most often found along riparian corridors. Found with increasing regularity in the southern Trans-Pecos close to the Rio Grande, and may be resident now in southern Brewster and Presidio counties.

Great Trinity Forest Management Plan

Wildlife Management

Great Blue Heron

(Ardea Herodias)

GREAT BLUE HERON

Ardea herodias

BACKGROUND The Great Blue Heron is the most widespread, and probably also the most familiar, of the herons and egrets found in Texas. Although Great Blue Herons are solitary birds for most of the year, they typically nest in loose colonies. The greatest concentrations of nesting Great Blues are on spoil and other islands on the central coast. In flight, Great Blues and other large herons fold their neck into an S-curve, bringing the head back to near the shoulders. Flying herons can be easily distinguished from cranes, which do not fold the neck at all in flight. A white subspecies, *A. h. occidentalis,* found primarily in southern Florida and the northern Caribbean, has strayed to Texas a few times. This subspecies was formerly known as the Great White Heron and was once considered a separate species.

IDENTIFICATION The largest heron found in the United States, the Great Blue Heron has a slaty blue-gray body plumage made up of long plumelike feathers. The head is white with a prominent black stripe starting behind the eye and ending in a thin black crest. The neck is long and gray with a black stripe, bordered in white, down the front. The thighs are rufous, and the long legs are dark.

SIMILAR SPECIES Sometimes confused with the Sandhill Crane (*Grus canadensis*) because they are both basically gray in color and are similar in size. Closer examination, however, reveals that the two species are not very similar in plumage. The Sandhill Crane is a uniform gray with a red cap of bare skin, and the Great Blue Heron actually has a much more ornate plumage.

HABITAT Almost all wetland habitats found in Texas. They can be found along the shores of large reservoirs or small ponds. They are also common in brackish and saltwater habitats as well.

STATUS AND DISTRIBUTION Uncommon to common summer resident throughout much of the state. Particularly common along the Coastal Prairies. During the fall and early winter, most birds move south out of the interior of the state to the Coastal Prairies. Large rookeries, or nesting colonies, are found at scattered locations across the state. They are especially common on coastal islands, where rookeries can contain many hundreds of nests. The white subspecies has been found on very rare occasions along the upper and central coasts.

Great Blue Heron. Photo by Tim Cooper.

Great Trinity Forest Management Plan

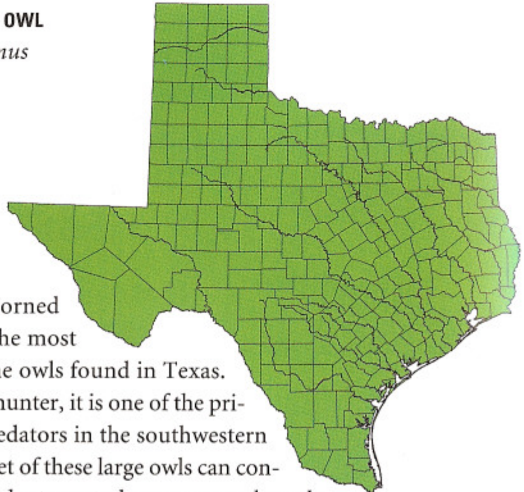
Wildlife Management

Great Horned Owl

(Bubo virginianus)

GREAT HORNED OWL

Bubo virginianus



BACKGROUND

The Great Horned Owl is easily the most powerful of the owls found in Texas. An aggressive hunter, it is one of the primary avian predators in the southwestern deserts. The diet of these large owls can consist of small rodents up to large mammals such as skunks and raccoons, and they have been known to take even larger prey, such as roosting hawks and even a Great Blue Heron. The reintroduction program for the Endangered Aplomado Falcon (*Falco femoralis*) was hampered by the heavy toll these owls took on the newly released young falcons. Great Horned Owls take up residence in many habitats, including in urban environments. In urban settings they feed primarily on rats, but they have been known to capture domestic animals as well. A Great Horned Owl can lift large prey items, even those that are heavier than its own weight. It will often come out to a prominent perch just before dark and watch for prey. It is a very early nester, starting as early as January.

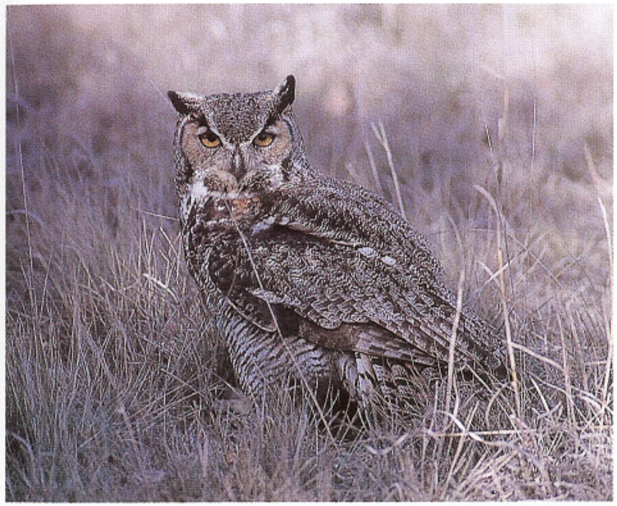
IDENTIFICATION This is a very large bird, easily the largest owl found in Texas. It has widely spaced ear tufts, but they can be inconspicuous at times. The plumage is heavily barred below and mottled with various shades of brown on the chest and upperparts, with a prominent white throat. The eyes are yellow.

SIMILAR SPECIES There are no widespread owls in Texas that are likely to be confused with this species. The Long-eared Owl (*Asio otus*), however, is similar in coloration and appearance. The Long-eared Owl is much smaller and slimmer, with more-

prominent ear tufts that are spaced close together. It lacks the white throat of the Great Horned Owl and has orangish brown patches at the base of the primaries. It is an uncommon to rare winter visitor to the state, with most records coming from the northern third. The Barred Owl (*Strix varia*) has a different pattern to its plumage and is found in dense woodlands. This forest owl also has dark eyes.

HABITAT This very adaptable owl can be found in a wide variety of habitats, in open woodlands, desert scrublands, and riparian corridors. The only habitat where it is not routinely found is dense closed-canopy forest.

STATUS AND DISTRIBUTION Common resident in all areas of the state except the Pineywoods, where it is uncommon. May be most abundant in the deserts and open scrub habitats of the Trans-Pecos.



Great Horned Owl. Photo by Mark W. Lockwood.

Great Trinity Forest Management Plan

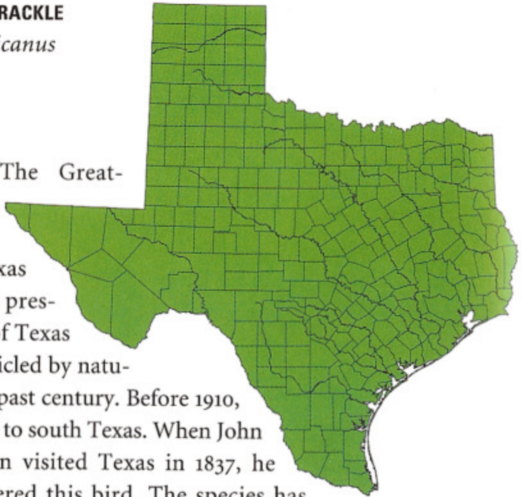
Wildlife Management

Great-tailed Grackle

(Quiscalus mexicanus)

GREAT-TAILED GRACKLE

Quiscalus mexicanus



BACKGROUND The Great-tailed Grackle is well known to urban Texas residents. Its presence in much of Texas has been chronicled by naturalists over the past century. Before 1910, it was restricted to south Texas. When John James Audubon visited Texas in 1837, he never encountered this bird. The species has readily adapted to, and taken advantage of, human changes in the landscape. By 1960 it had colonized the remainder of the Coastal Prairies and much of the central portion of the state, with breeding documented as far north as north-central Texas and the southern Panhandle. The remainder of the state, west of the Pineywoods, was colonized by the mid-1980s. This bird's adaptability to urban habitats has made it a pest in all of the cities in the state. During the day, flocks spread out over the urban landscape, feeding on lawns, parks, and golf courses. The real problem arises at night, when the birds congregate in very large roosting flocks. They seem to prefer open areas with scattered trees, such as parking lots at grocery stores and malls.

Great-tailed Grackle, male displaying. Photo by Tim Cooper.

IDENTIFICATION The male

Great-tailed Grackle, female. Photo by Mark W. Lockwood.

is unmistakable because of his large size—up to 17 inches in length including the long keel-shaped tail—and vocal manner. The male is black, with iridescent blue on the back and breast. The female is smaller and brown. The underparts are palest on the throat and upper breast. The eyes of both sexes are yellow.

SIMILAR SPECIES The two other species of grackles found in Texas provide the greatest identification challenge. The Common Grackle (*Q. quiscula*), which is common over the eastern three-quarters of the state, is notably smaller, with a much smaller tail. It also has iridescent plumage, but in Texas birds the iridescence is bronzy. The Boat-tailed Grackle (*Q. major*) is very similar to the Great-tailed, but it has brown eyes. The Boat-tailed is common along the Coastal Prairies south to Rockport, Aransas County.

HABITAT Found in disturbed habitats, including agricultural and urban areas. In the southern portion of the state, in open habitats with at least a few scattered trees.

STATUS AND DISTRIBUTION Abundant resident throughout most of the southern half of the state. Common farther north, but largely limited to urban areas. In the Pineywoods, very rare resident, particularly away from urban areas. In the Trans-Pecos, common to abundant in urban areas and rare to absent otherwise.

Great Trinity Forest Management Plan

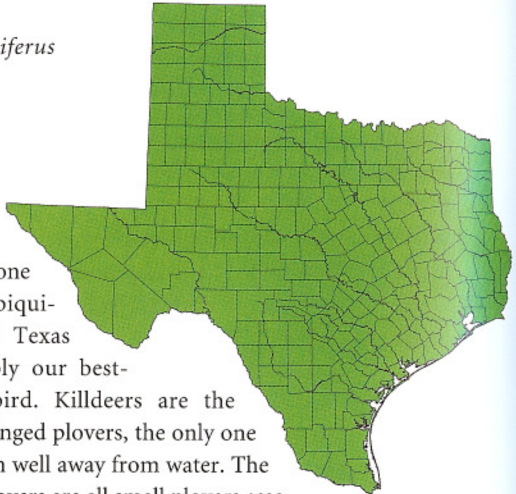
Wildlife Management

Killdeer

(Charadrius vociferous)

KILLDEER

Charadrius vociferus



BACKGROUND

The Killdeer is one of the most ubiquitous birds in Texas and is probably our best-known shorebird. Killdeers are the largest of the ringed plovers, the only one likely to be seen well away from water. The other ringed plovers are all small plovers associated with mudflats or coastal shorelines. The loud *kill-dee-dee* call of this species is the origin of its common and scientific names and identifies the species as much as any visual aspect. Perhaps equally well known is the conspicuous broken-wing display, used to distract potential predators from nests and young. The young are precocial, meaning they are fully feathered and ready to leave the nest as soon as they hatch. They almost immediately begin following the parents and searching for food. They are, of course, initially flightless and depend on the parents for protection.

IDENTIFICATION The Killdeer has brown upperparts and is white below. The two prominent black bands across its breast are a key field mark. The relatively long tail is primarily orange with a black subterminal band. Killdeer have long legs and often will run to escape predators or to avoid contact. Downy young have a single breast band, but this plumage is held for a very short time after hatching.

SIMILAR SPECIES The other ringed plovers are the most likely candidates to cause confusion, but all are much smaller and have only one breast band instead of two. Killdeer are often seen in the habitats frequented by these birds. The Piping Plover (*C. melodus*) and Snowy Plover (*C. alexandrinus*) are sandy gray above and thus are easily eliminated. The Semipalmated Plover's (*C. semipalmatus*) plumage pattern is similar, basically lacking the double breast band and orange tail. Indeed, juvenile Killdeer are occasionally confused with this species. The final ringed plover is Wilson's (*C. wilsonia*). Wilson's is found exclusively along the immediate coast and is similar in overall color, but it also lacks the double breast band and orange tail.

Killdeer. Photo by Tim Cooper.

HABITAT Found in almost all open habitats, including cultivated fields, vacant lots in urban areas, golf courses, pastures, and prairies. Also along shorelines, on mudflats, and other habitats normally associated with shorebirds.

STATUS AND DISTRIBUTION Common to abundant resident throughout the state. During the winter, even more common in the central and southern parts of the state as migrants arrive. Populations fluctuate greatly during the winter in the Panhandle, where it can be common some years and virtually absent in others.

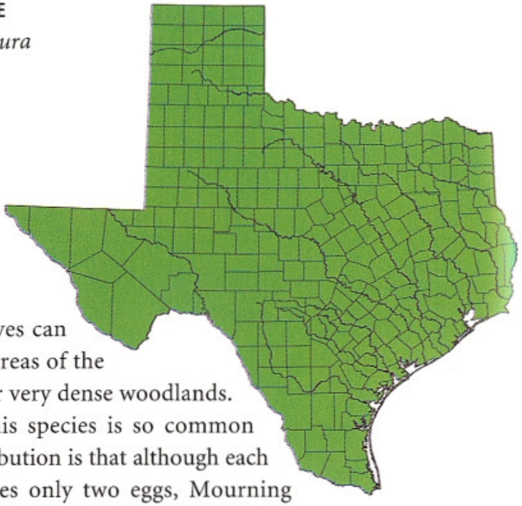
Great Trinity Forest Management Plan

Wildlife Management

Mourning Dove

(Zenaida macroura)

MOURNING DOVE
Zenaida macroura



BACKGROUND
Mourning Doves can be seen in all areas of the state except for very dense woodlands. One reason this species is so common across its distribution is that although each nesting includes only two eggs, Mourning Doves often nest five to six times per year. Occasionally, clutches of three or four eggs have been noted, but they are the result of more than one female laying eggs in the nest. The nest is a flimsy structure, and these doves rarely leave the eggs unattended.

IDENTIFICATION This medium-sized dove with grayish brown plumage has upperparts that are darker than the buffier underparts. The wing coverts have prominent black spots that are easily visible on perched birds, as they are on many dove species. Other plumage features include a black comma-shaped mark on the cheek and an area of iridescent feathers on the side of the neck. The tail is long and graduated, with white tips except on the central rectrices. Males have a bluish gray cap and nape, but this area is more olive-gray in females. Immature Mourning Doves have a scaly appearance to their body plumage, but they still have a graduated tail.

SIMILAR SPECIES The White-winged Dove is a larger species and lacks a long, pointed tail. In addition, the White-winged has a large white stripe in the wings that is visible perched or in flight. The Inca Dove (*Columbina inca*) and Common Ground-Dove (*Columbina passerina*) are smaller and look very scaled. These

species are unlikely to be confused with an adult Mourning Dove, but it might be an issue with an immature bird. The Inca Dove has a long tail with white outer rectrices that are not graduated and has rufous primaries. The Common Ground-Dove has a very short, rounded black tail, and its primaries are rufous as well. The introduced Eurasian Collared-Dove is much larger and heavier bodied, with a long square-tipped tail and much paler body plumage. As the name suggests, these doves have a distinct black line across the back of the neck as adults, but this mark is missing in immature birds.

HABITAT Found in almost all habitats in Texas with the exception of dense woodlands. Indications are that Mourning Doves are being displaced by White-winged and Eurasian Collared-Doves in urban areas.

STATUS AND DISTRIBUTION Common to abundant summer and winter resident throughout the state. Those that nest in Texas largely leave in the fall, only to be replaced by migrants from northern breeding areas. This species is the most abundant game bird in North America.

Mourning Dove. Photo by Tim Cooper.

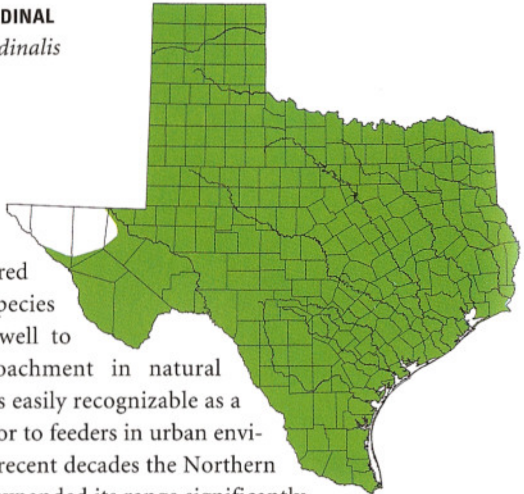
Great Trinity Forest Management Plan

Wildlife Management

Northern Cardinal

(Cardinalis cardinalis)

NORTHERN CARDINAL
Cardinalis cardinalis



BACKGROUND
The Northern Cardinal is the original red bird. This species has adapted well to human encroachment in natural habitats and is easily recognizable as a common visitor to feeders in urban environments. In recent decades the Northern Cardinal has expanded its range significantly, taking advantage of logging and other practices that create more open habitats. The limiting factor in its expansion to the west seems to be annual rainfall. The common name "cardinal" is derived from the similarity of the bird's plumage to robes worn by Roman Catholic cardinals, but the name has been applied to a variety of other species that have similar body structure and size. In the late 1800s, it was a popular cage bird, and thousands were trapped for the pet trade and shipped to Europe, as well as being sold in the United States. Although the Northern Cardinal is not known as a migratory bird, some seasonal movements have been noted in Texas. Whether the movements are more local in origin or a larger migration in search of better food resources is not well understood.

Northern Cardinal, male. Photo by Tim Cooper.

IDENTIFICATION The male is fairly bright red overall, with a crest. Its black face extends back just past the eyes. The female is buffy brown overall, with red wings and tail. She also has a black face and a reddish crest. Both sexes have a heavy red bill. Immature birds are similar to the adult female but have a black bill and lack the black face until the post-juvenile molt.

SIMILAR SPECIES The male is unmistakable with its red plumage and crest. The female, however, is similar to the related Pyrrhuloxia (*C. sinuatus*), which is common in similar habitats in much of the Southwestern portion of the state. In general, the Pyrrhuloxia inhabits more arid habitats, but there are places where the species are seen together. The plumage of the Pyrrhuloxia is grayer overall, and the bird has a yellow bill with a much more strongly curved culmen.

Northern Cardinal, female. Photo by Mark W. Lockwood.

HABITAT Found in woodlands and brushlands. Also common in urban environments.

STATUS AND DISTRIBUTION Common to abundant resident throughout most of the state. In the Trans-Pecos, uncommon to locally common resident in the southern counties, and rare visitor at all seasons in the northern half. In the Panhandle and South Plains, rare and local resident in the western counties.

Great Trinity Forest Management Plan

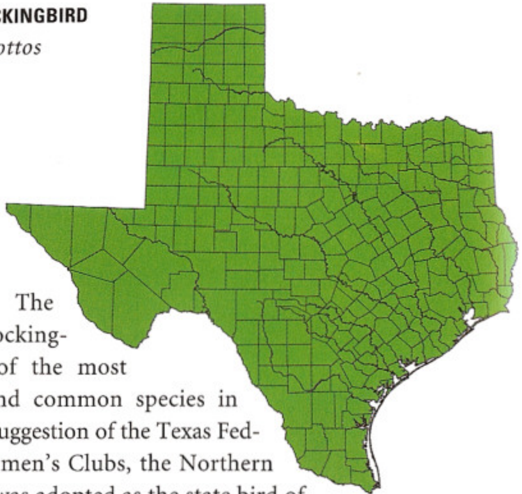
Wildlife Management

Northern Mockingbird

(Mimus polyglottos)

NORTHERN MOCKINGBIRD

Mimus polyglottos



BACKGROUND The Northern Mockingbird is one of the most widespread and common species in Texas. At the suggestion of the Texas Federation of Women's Clubs, the Northern Mockingbird was adopted as the state bird of Texas in January 1927. It is best known for its extraordinary repertoire of song and also for its persistence in singing, even at night. It is believed that most of the birds that sing at night are actually unmated males. The full moon appears to spur them into song. The Northern Mockingbird sings virtually throughout the year, with the most consistent and varied singing between February and September. The female also sings but is not as persistent or as loud. Females rarely sing in the summer, when the male is particularly vocal in defending the breeding territory. During the breeding season, these birds are often seen flashing their wings to show the large white patches. Whether this is a territorial display or a hunting technique is unknown.

IDENTIFICATION This bird has gray upperparts with grayish white underparts. The wings are also gray, with two white wing bars and a large white patch that is prominent when the wing is spread. The tail is long and edged with white. Immature birds are similar to adults, with faint gray streaks on the underparts.

SIMILAR SPECIES The Loggerhead Shrike (*Lanius ludovicianus*) has a similar plumage pattern, with a prominent black mask, smaller white patches on black wings, and greater contrast between the upperparts and underparts. Townsend's Solitaire

(*Myadestes townsendi*) is darker gray overall and lacks the large white patches in the wing and tail. The Gray Catbird (*Dumetella carolinensis*) has much darker gray plumage and also lacks the white in wings and tail. The Sage Thrasher (*Oreoscoptes montanus*) could be confused with the immature Northern Mockingbird, it likewise lacks the distinctive plumage pattern of the Northern Mockingbird.

HABITAT Found in open areas and along forest edges. This makes this species well adapted for using urban habitats. Males normally use higher perches for singing their advertising song and later for territorial defense. Northern Mockingbirds are also found in meadows and other opening in forests.

STATUS AND DISTRIBUTION Abundant to common resident throughout the state. One of the most widespread and common birds in Texas, they are conspicuous by their song. Seasonal movements are suspected in Texas, and individuals from northern migratory populations may account for apparent influxes of mockingbirds during the winter.

Northern Mockingbird. Photo by Tim Cooper.

Great Trinity Forest Management Plan

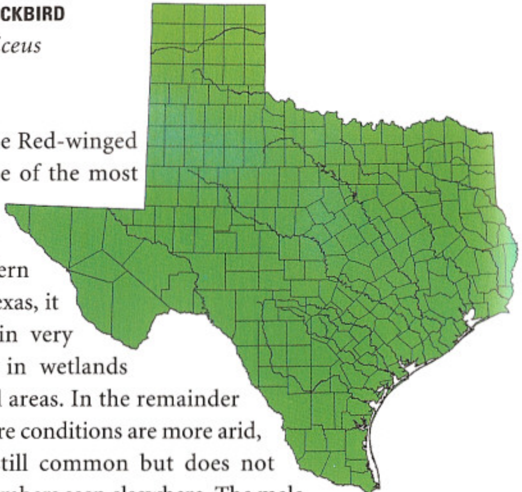
Wildlife Management

Red-winged Blackbird

(Agelaius phoeniceus)

RED-WINGED BLACKBIRD

Agelaius phoeniceus



BACKGROUND The Red-winged Blackbird is one of the most abundant birds in North America. In the eastern two-thirds of Texas, it can be found in very large numbers in wetlands and agricultural areas. In the remainder of the state, where conditions are more arid, the species is still common but does not approach the numbers seen elsewhere. The male can effectively hide his scarlet shoulders when at rest, but moments later he can show them off in a courtship display. Males are very territorial and arrive in breeding areas well before the females. The species is highly polygynous. One male typically has three or four females nesting within his territory, but a male has been found with as many as 15 different females. Although almost all territories have multiple females, the male within a territory is not necessarily the parent to all their offspring. Studies have shown that up to half of the offspring can come from neighboring males.

Red-winged Blackbird, male. Photo by Greg W. Lasley.

IDENTIFICATION This is a medium-sized blackbird, smaller than a female Great-tailed Grackle (*Quiscalus mexicanus*). The male is glossy black with prominent red shoulders. The shoulders are scarlet bordered with a thin yellowish or dull band. The bill, eyes, and feet are black. The female is blackish brown overall and heavily streaked below, with a prominent pale supercilium that separates a darker cap and auriculars. The face can have a wash of pink or buff. Males do not attain full adult plumage until their third year. Immature males can look much like a female, with dull red shoulders, or like an adult male.

Red-winged Blackbird, female. Photo by Greg W. Lasley.

SIMILAR SPECIES The male is unmistakable when the shoulder is seen. The female can be distinguished from all other Texas blackbirds by the heavily streaked underparts and mottled upperparts. Immature Brown-headed Cowbirds (*Molothrus ater*) are streaked below but uniform in plumage pattern above.

HABITAT Found in a variety of habitats, but most often in wetlands. Also, sometimes in very large numbers, in agricultural areas, particularly grain and corn fields. Also in open woodlands.

STATUS AND DISTRIBUTION Abundant to locally uncommon resident throughout the state. More localized during the breeding season because of the spotty availability of nesting habitat, particularly in the western half of the state. More widespread and often found in large flocks during the remainder of the year as migrants join the resident population. Some wintering roosts reportedly contain a million or more birds.

Great Trinity Forest Management Plan

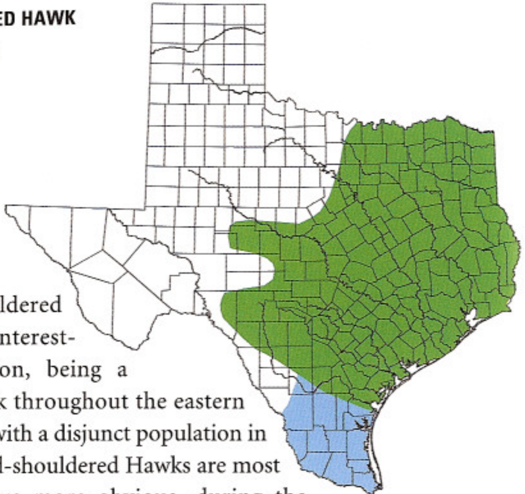
Wildlife Management

Red-shouldered Hawk

(Buteo lineatus)

RED-SHOULDERED HAWK

Buteo lineatus



BACKGROUND

The Red-shouldered Hawk has an interesting distribution, being a common hawk throughout the eastern United States with a disjunct population in California. Red-shouldered Hawks are most vocal, and thus more obvious, during the spring when they form pairs. The pair often circles well above the trees, calling almost constantly. For most of the rest of the year, these birds are less conspicuous as they attend to the nest and forage. This forest-dwelling raptor has an unusual hunting behavior in which it sits very still on a perch watching for prey to drop upon. One of the most interesting records of this hawk in Texas involved an individual that successfully nested with a Gray Hawk (*Buteo nitida*) in Big Bend National Park in 1989.

IDENTIFICATION This is a large, long-winged hawk with narrow white barring on dark wings. The shoulders are obviously rusty, contrasting with brown flight feathers. The underparts have rufous barring, although the intensity of the color is quite variable. The tail is moderately long and narrowly banded. In flight, the base of the primaries is pale, showing a translucent window area. Immature birds have brown upperparts and heavily streaked white underparts. There is normally some evidence of the rusty red shoulder.

SIMILAR SPECIES The most similar raptor is the Broad-winged Hawk (*Buteo platypterus*), but it is much smaller and has a more compact body type. In addition, the tail is shorter and widely barred. The wings are more pointed, and from below the

light-colored flight feathers are outlined in black. An immature Broad-winged can be identified by the dark whisker streak and the same wing shape and color pattern. The adult Cooper's Hawk (*Accipiter cooperii*) has a similar coloration pattern, but its overall shape is more streamlined and the tail is much longer.

HABITAT Found in mature woodlands near water. Riparian corridors are the primary habitat in many areas of the state, particularly in the western portion of the species range. They seem to be adaptable to human intrusion and can be found in human-altered habitats, including urban areas.

STATUS AND DISTRIBUTION Common to uncommon resident throughout the eastern two-thirds of the state. In the remainder of the state, this hawk is a rare to casual visitor and is found primarily along wooded drainages. In south Texas, this species is primarily a winter resident, although there are records from all seasons.

Red-shouldered Hawk. Photo by Greg W. Lasley.

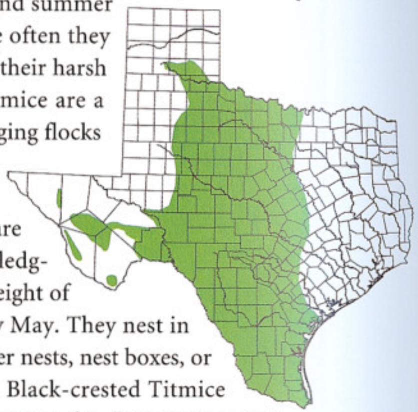
Great Trinity Forest Management Plan

Wildlife Management

Tufted Titmouse

(Baeolophus bicolor)

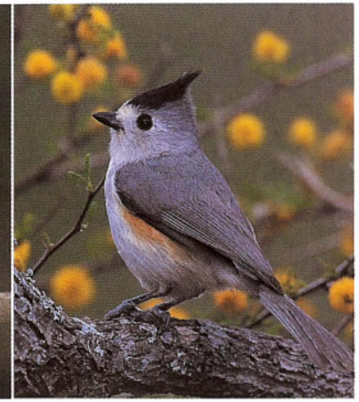
TUFTED TITMOUSE
Baeolophus bicolor
and
BLACK-CRESTED TITMOUSE
Baeolophus atricristatus



BACKGROUND These noisy birds are a common sight in woodland habitats in most of the state. They are usually seen in pairs, or in family groups during the summer and early fall. Although they can be hard to find at times during the spring and summer as they forage silently, more often they announce their presence by their harsh calls. During the winter, titmice are a frequent component of foraging flocks and are often the first to announce the presence of a potential predator. Titmice are early nesters, often having fledglings out of the nest at the height of migration in April and early May. They nest in cavities, using old woodpecker nests, nest boxes, or natural cavities. Tufted and Black-crested Titmice were formerly considered one species. In a narrow area where the ranges of these species come together, hybrids outnumber the parental types. The hybrids most commonly have a dark chestnut patch on the forehead with a crest that varies from light to charcoal gray.

IDENTIFICATION These small, agile birds have a long tail, prominent crest, and gray overall plumage with orange-buff flanks. The underparts are generally paler gray than the upperparts. The Tufted Titmouse has a gray crest with a black forehead. The Black-crested has a black crest with a pale gray forehead, often with a brownish wash. The Black-crested Titmouse is typically smaller than its eastern counterpart. Juveniles of both species are similar to adults with short crests. Young Black-crested Tit-

Tufted Titmouse. Photo by Mark W. Lockwood.



Black-crested Titmouse. Photo by Greg W. Lasley.

mice, however, often have a gray crest for a short period of time.

SIMILAR SPECIES Within their range, there are no other species that can be confused with these titmice. A juvenile with a gray crest could be confused with the Juniper Titmouse (*B. ridgwayi*), which occurs in Texas only in the Guadalupe Mountains. The Black-crested juveniles, however, normally have some hint of buffy coloring on the flanks.

HABITAT Both species inhabit woodlands. Tufted Titmice are found primarily in deciduous forests as well as urban areas and parks. Black-crested Titmice are found in the oak woodlands of the Hill Country and Trans-Pecos and scrub habitats of the South Texas Brush Country and Rolling Plains.

STATUS AND DISTRIBUTION Both species are common, with the Tufted found in the eastern third of the state and the Black-crested in the west. The Tufted Titmouse range is east of a line from the eastern edge of the Rolling Plains and Edwards Plateau south to Refugio County. The Black-crested Titmouse range is west of that line south to the Lower Rio Grande Valley and north to the northern Rolling Plains. In the Trans-Pecos, the Black-crested is more localized and restricted to the larger mountain ranges. It is an irregular visitor to the High Plains and the Guadalupe Mountains.

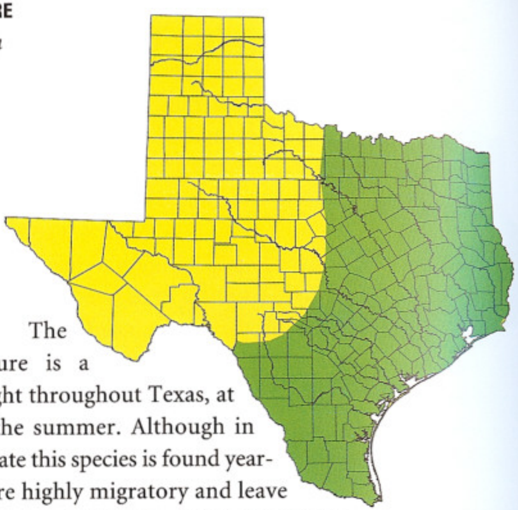
Great Trinity Forest Management Plan

Wildlife Management

Turkey Vulture

(Cathartes aura)

TURKEY VULTURE
Cathartes aura



BACKGROUND The Turkey Vulture is a ubiquitous sight throughout Texas, at least during the summer. Although in much of the state this species is found year-round, they are highly migratory and leave much of the western half of the state in winter. In fact, in those regions the return of the Turkey Vulture is a sign of spring. A well-known behavior of these birds is to patrol highways looking for road-killed animals on which to feed. Turkey Vultures have a keen sense of smell, something that is lacking in most other species. Researchers were able to uncover this characteristic by hiding carrion, which the vultures were still able to detect. Because vultures have less oil in their feathers than some other birds, they often sit with their wings open to the sun to dry, particularly in the early morning. When soaring, Turkey Vultures hold their wings in a shallow V, called a dihedral. The dihedral makes it easy to distinguish them at a distance from large raptors, such as eagles, which hold their wings in the same plane as the body. Turkey Vultures are often referred to as buzzards, which is the common name of large hawks in Europe.

IDENTIFICATION Large soaring birds with a six-foot wingspan, adults have a small, naked, red head, white bill, and a blackish brown body, wings, and tail. Immature birds have a gray head and bill. In flight, the red head of the adult is often not readily visible. The flight feathers of these birds are gray, contrasting sharply with the dark coloration of the body. These feathers can appear almost white in certain lighting conditions.

SIMILAR SPECIES There is one other species of vulture found in Texas, the Black Vulture (*Coragyps atratus*). Black Vultures have a white patch in the outer primaries and have much shorter, broader wings. In addition, they have a short, square tail, the combination of which gives them a very different shape in flight. Black Vultures also have a naked head, but the skin is dark gray to black. The profile in flight of the Zone-tailed Hawk (*Buteo albonotatus*) is similar to a Turkey Vulture's, but the hawk has a feathered head and white bands in its tail.

Turkey Vulture. Photo by Tim Cooper.

HABITAT Found in open habitats, including everything from fields and pastures to urban environments. These gregarious birds are well known for roosting in groups on power-line towers. Vultures nest in small caves and other sheltered areas.

STATUS AND DISTRIBUTION Common to locally abundant summer resident throughout the state. Leaves most of the western half of the state during the winter. Common during winter in the eastern half of the state and in south Texas. In late fall, very large numbers migrate through southern Texas on their way to wintering areas farther south.

Great Trinity Forest Management Plan

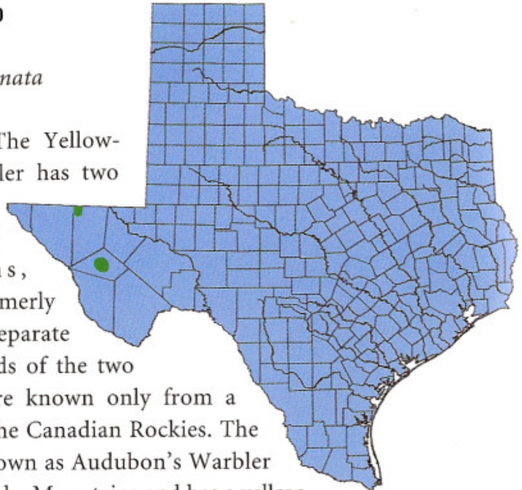
Wildlife Management

Yellow-rumped Warbler

(Dendroica coronata)

YELLOW-RUMPED WARBLER

Dendroica coronata



BACKGROUND The Yellow-rumped Warbler has two distinctively plumaged populations, which were formerly considered separate species. Hybrids of the two populations are known only from a small area in the Canadian Rockies. The population known as Audubon's Warbler nests in the Rocky Mountains and has a yellow throat and darker underparts. The Myrtle Warbler nests from Alaska east to New England and is paler with a white throat. The two forms may be elevated to species status again, and both commonly occur in Texas.

IDENTIFICATION Both forms have a bright yellow rump and crown, broken white eye-rings, and large white tail spots. The adult male Myrtle has a white throat and a black mask including the lores through the auriculars. The mask is bordered above by a thin white supercilium. The upperparts are blue-gray with black streaking on the back. The underparts are white with a band of black streaks across the breast and down the flanks. The flanks are largely yellow, bordered by the broken streaks of black. The female is similar to the male, but with brown upperparts. First-fall birds are brownish with a brownish white throat and indistinct markings on the body. Audubon's Warbler has a yellow throat and generally much more black on the underparts. Its plain blue-gray face has a broken white eye-ring. The female is much duller, with brownish upperparts and more mottled underparts. First-fall birds are brownish with a plain face and a dull yellow throat.

Yellow-rumped Warbler, breeding plumage, Myrtle form. Photo by Tim Cooper.

Yellow-rumped Warbler, winter plumage, Myrtle. Photo by Greg W. Lasley.

SIMILAR SPECIES These birds are very distinctive and unlikely to be confused with other warblers. Dull female Cape May Warblers (*D. tigrina*) also have a yellow rump, but they are more evenly streaked below and usually show some yellow behind the auriculars. The Magnolia Warbler (*D. magnolia*) also has a yellow rump, but it has yellow underparts in all plumages. Separating first-winter birds of the two forms can sometimes be challenging. In most cases, Audubon's has some yellow in the throat and a darker, plainer face. The Palm Warbler (*D. palmarum*), particularly the duller plumaged birds from the western populations, can be confusing, but its supercilium and yellow undertail coverts should be more distinct. In addition, it habitually wags its tail as it forages.

HABITAT Found in brushy and woodland habitats throughout the state. The breeding Audubon's Warblers in the Trans-Pecos are found in mixed deciduous woodlands.

STATUS AND DISTRIBUTION Common to abundant migrant over the entire state. Common to abundant winter resident in all areas of the state except the Panhandle, where it is rare to uncommon. Audubon's Warbler is a rare to locally uncommon summer resident in the higher elevations of the Davis and Guadalupe mountains of the Trans-Pecos. It begins to appear in the state in early September, and spring migrants are gone by mid-May. The Myrtle Warbler is more common in the eastern two-thirds of the state, although it is present in all areas. Audubon's Warblers are uncommon in the Trans-Pecos, Panhandle, and South Plains, becoming scarce farther east and south.

<u>Great Trinity Forest Management Plan</u>

Wildlife Management

Gray Treefrog

(<u>Hyla</u> <u>versicolor</u>)

Gray treefrog *Hyla versicolor*

Gray Treefrog

Hyla versicolor

Note This species and Cope's gray treefrog, *Hyla chrysoscelis,* are identical in their physical descriptions, as well as range, habitat, and behavior patterns. They are distinguished from each other only by differences in their calls and by their chromosome counts. In the field, observers can make the distinction only by carefully monitoring the calls. *H. chrysoscelis* has the faster trill, but without comparison the calls may be difficult to tell apart. The chromosome count of *H. versicolor* is twice that of *H. chrysoscelis.*

Description 1¼ to 2⅜ inches total length. This treefrog is well camouflaged with its coloration of green or brown to gray. It has several large dark blotches on its back that may be interpreted as an irregular cross shape. It usually has a dark-edged light spot under the eye. The legs usually have dark bars, and the hidden surfaces of the hind legs are bright yellow-orange. Its skin is rough with small warts. It has large pads on the tips of its long toes.

Voice The call is a high-pitched musical trill, slower than that of *H. chrysoscelis.* It can be heard in the spring and early summer during breeding.

Range Found throughout the eastern half of the state, not including the Rio Grande Valley.

Habitat It is at home in wooded areas along creeks and rivers, where trees and shrubs overhang or grow in the water.

Behavior This primarily nocturnal treefrog lives most of its life in the trees or shrubs near or in shallow water. It descends only to chorus and to breed.

Reproduction Breeding takes place from mid-March through July or even later in warmer areas. Tadpoles transform at about ⅝ inch.

Great Trinity Forest Management Plan

Wildlife Management

Gulf Coast Toad

(Bufo valliceps valliceps)

Gulf Coast toad
Bufo valliceps valliceps

Gulf Coast Toad

Bufo valliceps valliceps

Description 2 to 5⅛ inches total length. This medium-sized, rather flat toad is distinctively marked by a broad dark stripe down each side, bordered above by a light stripe. It has a third light stripe down the middle of its back beginning on its head. General coloration varies from yellowish brown to almost black. On males the throat is yellowish green. Most individuals have a distinct narrow dark line running the length of the upper lip just above the pale lip area. The prominent cranial crests form a depression on top of the skull. The ridges of the crests may be dark. Triangular parotoid glands are connected to the cranial crest behind the eyes.

Voice The vocal sac on this toad is large and round when extended. The call is a short, flat trill of 2 to 6 seconds that is repeated often at intervals of 1 to 4 seconds.

Range Found in most of East Texas, except the northeastern corner, and throughout Central and South Texas.

Habitat This toad is at home in a variety of moist habitats, including man-made ditches, backyard gardens, dump sites, and storm sewers. It is also found on barrier beaches along the coast, as well as on coastal prairies.

Behavior Most active at twilight, this toad can be seen under streetlights at night or in other spots where it can feed on insects drawn to lights.

Reproduction Breeding takes place from March to September. It lays eggs in strings of jelly, usually in double rows. Tadpoles transform after 20 to 30 days.

Great Trinity Forest Management Plan

Wildlife Management

Southern Leopard Frog

(Rana sphenocephala)

Southern leopard frog *Rana sphenocephala*

Southern Leopard Frog

Rana sphenocephala

Description 2 to 5 inches record maximum length at maturity. This slender frog has a narrow, pointed head and long hind legs and toes. General coloration varies from tan to several shades of brown to green, and an individual may have a combination of these colors. The back is usually covered with dark brown spots between distinct light-colored dorsolateral ridges, and the sides may have some spotting. Large brown spots on the legs may create the effect of bands. It has a light line along the upper jaw and usually a light spot in the center of the tympanum.

Voice The paired vocal sacs, when deflated, form pouches under the jaw on either side. During calls, the sacs inflate to spheres. The call is a rapid series of abrupt, deep croaks, creating a guttural trill. The trill rate may be as much as 13 per second. Males will call from land or while floating in shallow water.

Range Found throughout East Texas and into the south-central region.

Habitat This frog prefers the environs of shallow water, but it may be seen some distance from water if there is sufficient vegetation to provide protection. A distinguishing characteristic is its ability to live in brackish marshes along the coast.

Behavior This frog skillfully eludes predators by jumping into nearby water and then returning to the bank underwater, while the predator continues looking near the point of entry into the water. The frog is primarily nocturnal, hiding during the day in vegetation at water's edge. During summer months, it may wander some distance from water, but it stays in moist vegetation.

Reproduction Breeding takes place year-round, and the female lays eggs in shallow water.

Great Trinity Forest Management Plan

Wildlife Management

Smallmouth Salamander

(Ambystoma texanum)

Terry L. Vandeventer

Terry L. Hibbitts

Smallmouth salamander *Ambystoma texanum*

Smallmouth Salamander

Ambystoma texanum

Description 4½ to 7 inches head-body length. It has a small head and mouth and large body. The relatively long tail may be as long as the head and body. It has strong legs, with 4 toes on the front feet and 5 on the back. It is black or dark brown top and bottom, and the dorsum is usually covered with a variable pattern of light gray speckles resembling lichen. The light markings are usually more prominent on the sides. The belly may have tiny light flecks. It has 14 or 15 costal grooves.

Range Found throughout East Texas and east-central parts of the state from the northern borders to the Gulf of Mexico.

Habitat This salamander requires abundant moisture, such as in wooded areas with swamps or in river bottoms. It may be found in cultivated farmlands near sources of water or in mammal burrows.

Behavior Nocturnal in its habits, it is particularly shy and usually remains underground or finds shelter under fallen logs or other debris near ponds or in swamps. During the breeding season, it may emerge and migrate at night or during rain to congregate in groups at nearby ponds or streams. If threatened, it may elevate its tail and wave it from side to side.

Reproduction It breeds from late January until April and deposits eggs in streams or pools. The female lays up to 700 eggs, which attach, singly or in small clutches, to underwater debris, including the undersides of rocks.

Great Trinity Forest Management Plan

Wildlife Management

Western Lesser Siren

(Siren intermedia nettingi)

William W. Lamar

Western lesser siren
Siren intermedia nettingi

Western Lesser Siren

Siren intermedia nettingi

Description Record head-body length of 19¾ inches. This eel-like species is an aquatic permanent larvae that is identifiable by its 2 small legs just behind the large external gills. The feet have 4 toes each. It also has 3 gill slits on each side. The sexes are indistinguishable in color and markings, but the male is larger than the female. The dorsal surfaces are olive to dark brown or gray with a scattering of tiny black spots. The belly is dark with many light spots. Spotting may not be apparent on the darker specimens. Immature specimens may have a red band across the snout and along the side of the head. The body is long, and the head is relatively large. The small eyes are lidless. The long, slender tail is pointed at the tip and vertically compressed, with a fin running its length. Although it does have lungs, it absorbs oxygen from the water through 3 pairs of well-developed gills. It has 34 to 35 costal grooves.

Range Found throughout the eastern third of the state and south about two thirds of the way down the coastline.

Habitat This siren is at home in warm shallow waters with submerged vegetation, such as in muddy ponds, lakes, rice fields, irrigation ditches, and swamps.

Behavior Nocturnal in its habits, during the day it burrows into submerged debris or silt in shallow water. It is primarily carnivorous and forages at night for its diet of crawfish, worms, and mollusks. It may ingest some plant material along with its preferred prey. It makes a clicking sound when it is approached or surfaces for air, and it may yelp when captured. It is difficult to handle because it squirms vigorously. If its habitat dries up, it burrows into the mud and secretes a mucous cocoon that dries into a protective covering, allowing it to survive a dry spell of up to 2 months. It emerges again when rains fill its pool.

Reproduction Breeding takes place in late winter, and the female deposits about 200 eggs in early spring in a debris-covered cavity in shallow water. The larvae are about ½ inch at hatching, and they are sexually mature in 2 years.

Great Trinity Forest Management Plan

Wildlife Management

Ground Skink

(Scincella lateralis)

190. Ground Skink

Scincella lateralis

Abundance/Range: This is an abundant lizard throughout most of its extensive range. It may be found from the Pine Barrens of New Jersey and eastern Kansas southward to southern Texas and throughout Florida and its Keys (except for the Everglades). It occurs in urban, suburban, and open woodland habitats.

Habitat: This secretive little skink may be seen skittering away from approaching lawnmowers in urban yards, darting from the cover of one fallen leaf to another. It occurs in dry upland woodlands as well as along stream and pond

190. Ground skink

edges. The ground skink can swim if necessary. These tiny lizards often hide beneath logs, boards, and other ground litter.

Size: This slender lizard may attain 5½ inches in total length. The tail is about 125% of the SVL. Hatchlings are about 1¾ inches in total length.

Identifying features: This active little lizard is of an overall dark coloration. The broad, dark brown dorsolateral stripes, which extend from the snout to well on to the tail, separate the light brown dorsum from the grayish tan sides. There is no light striping. The top of the head may be coppery colored, especially on juveniles and breeding males. The tail is not contrastingly colored. The legs are tiny. Each foot bears five toes.

Similar species: The four-lined and short-lined skinks have at least vestiges of light lines and, if young, blue tails. The many-lined skink and the patterned phase of the variable skink have many dark dorsal and lateral lines. The nonpatterned phase of the variable skink lacks a brown back. The sand skink is light colored with a reduced number of toes. The various races of the mole skink have a contrasting tail color and (often) light lines.

Great Trinity Forest Management Plan

Wildlife Management

Northern Green Anole

(Anolis carolinensis carolinensis)

155. Northern Green Anole

Anolis carolinensis carolinensis

Abundance/Range: This remains a common lizard over most of its extensive range. It is reduced in numbers in South Florida. This lizard ranges from northeastern North Carolina and eastern Tennessee to Florida (including the Keys) and central Texas.

Habitat: This anole is persistently arboreal. It is seen in shade trees and shrubs, on walls and fences, and can be abundant in tall native grasses. It is also common in isolated cypress heads and pine-palmetto scrublands. It often hangs head down on trunks, wooden fence posts, and other such vantage points.

Size: Large males may attain a total length of 8 inches. The tail is nearly twice as long as the SVL. Females are noticeably the smaller sex. Hatchlings measure about 2¼ inches in total length.

155. Northern green anole

Identifying features: Green anoles have the ability to undergo dramatic and rapid color changes. Green, gray, brown, and combinations of these are the common colors. Resting and content anoles tend to be of some shade of brown. They are darker when cold, and turn a pasty gray when overly warm. Disturbed or frightened anoles may be patchy brown and green. Males involved in aggression, including territorial displays, are often bright green with a nearly black ear patch. Breeding males are often green but lack a significantly darkened ear patch. In some populations, South Florida among them, indications of darker dorsal and dorsolateral streaking may be present. Female green anoles (and some males) have a light vertebral line. Male northern green anoles have a large, decidedly pink dewlap. Females occasionally have a tiny pink dewlap, but more often have none.

Similar species: Throughout most of its range, this is the only small color-changing lizard. However, in Dade and Broward counties, Florida, two look-alike species are found. These are the Hispaniolan green and the Cuban green anoles. These can be very difficult to differentiate and both also resemble the northern green anole. The pale-throated green anole can be differentiated by its grayish to white dewlap color.

Additional Subspecies

156. The Pale-throated Green Anole, *Anolis carolinensis seminolus*, was described in 1991. This subspecies, restricted to southwest Florida, has a gray, white, or greenish dewlap. All else about this form, including appearance and habits, is identical to the northern green anole.

Great Trinity Forest Management Plan

Wildlife Management

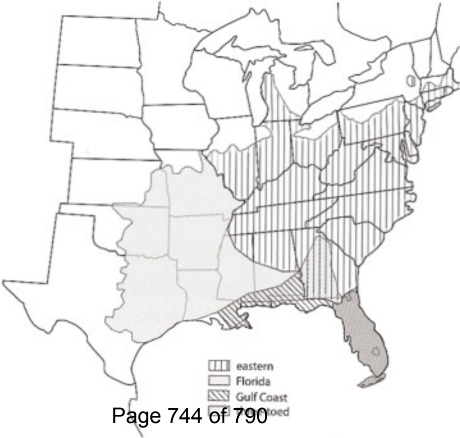
Eastern Box Turtle

(Terrapene carolina carolina)

64. Eastern Box Turtle

Terrapene carolina carolina

Abundance/Range: Many populations of this once common turtle are now seriously reduced. This box turtle ranges westward and southward from eastern Massachusetts to western Illinois and



64. Eastern box turtle

extreme northeastern Florida. Habitat degradation (including fragmentation, which often brings the turtle in contact with vehicles) and collecting for the pet trade have accounted for the removal of many box turtles of all races from the gene pool.

Habitat: The eastern box turtle may be found in open mixed woodland, in damp pasture and meadow edges, and near swamps and marshes. These terrestrial turtles may enter shallow water but seldom actually swim.

Size: Males attain a carapace length of a little more than 7½ inches. Females are somewhat smaller. Hatchlings are about 1 inch long.

Identifying features: The eastern box turtle is high domed, roughly of oval shape (when viewed from above), and of variable color. The carapace, head, neck, and limbs of the eastern box turtle are usually of some shade of brown. The carapace is adorned with irregular olive, orange, or yellow markings. The large scales on the anterior of the forelimbs are often yellow or orange. Depending on the color scheme, some examples may be quite dull in coloration while others are very bright. The plastron may be of a color similar to the carapace, or be somewhat differently colored. Males often have bright red irises; the irises of the females are buff or brown. Males, which are the larger sex and which have a variable degree of flaring to the rear marginal scutes, have a prominent concavity in the rear lobe of the plastron. Hatchlings are usually an olive brown with a single pale yellow spot on each carapacial scute. This race usually has 4 toes on the hind feet.

Similar species: Other than the box turtles, only the Blanding's and mud turtles have strongly hinged plastrons. Both are strongly aquatic. The Blandings turtle is smoothly domed but elongate and has a notched (not beaked) upper jaw. The plastron of the mud turtles has two hinges and does not form a complete cover for the head, limbs, and tail.

Additional Subspecies

65. The Florida Box Turtle, *Terrapene carolina bauri*, has a narrow, highly domed carapace with the highest point posterior to midpoint. Its color is deep brownish black to black with radiating yellow lines and a yellow vertebral keel. There are two yellow stripes on the sides of the face, which is rather light in color. The skin of the leg apices and neck is also light. The plastron is yellow with variable dark markings. An adult size of 5½–7½ inches is attained. Hatchlings are colored like the adults, but the yellow carapacial radiations are broken into irregular spots. The vertebral keel is yellow. The eyes of both sexes are dark. This race is found throughout the Florida peninsula and immediately adjacent southeastern Georgia. Most Florida box turtles have only 3 toes on each hind foot. Adult males have a prominent concavity in the rear lobe of their plastron. This helps them remain positioned atop the female for breeding.

65. Florida box turtle, female with eggs

66. Gulf Coast box turtle

66. The Gulf Coast Box Turtle, *Terrapene carolina major*, is the largest and most aquatic of these interesting turtles. Males commonly attain a carapace length of 7½ inches, and more rarely may reach 8½ inches. It may occasionally be seen walking or foraging on the bottom of ponds, puddles, or canals, and also forages terrestrially. This big dark box turtle is a resident of the woodlands, stream and canal edges, pinewoods, and marshes of Florida's southern panhandle. It readily intergrades with box turtles of abutting subspecies.

The ground color of the Gulf Coast race is brown or black, and the variable carapacial markings are yellowish or olive. Males often have red irides; those of the females are dark. The carapace of this race is depressed centrally. The plastron is usually darkest anteriorly and males have a prominent concavity in the rear lobe. This race usually has 4 toes on each hind foot. The posterior marginals of aged male Gulf Coast box turtles flare prominently. Old males often have a variable amount of white on their faces. This may be restricted to the anterior chin and mandibles or so extensive that it involves the whole head.

67. The Three-toed Box Turtle, *Terrapene carolina triunguis*, ranges westward from central eastern Alabama to eastern Texas and eastern Kansas.

This is one of the least colorful of the box turtles. The carapacial ground color is horn, olive, tan, or buff, with or without lighter radiations or teardrop-shaped

67. Three-toed box turtle

markings. Both males and females have brownish red eyes. The plastron is yellowish or olive and devoid of markings. Males often lack the rear-lobe plastral concavity that is so prominent in other races. Red and/or white facial markings are often present. Males may attain 6¼ inches in total length, but females are seldom more than 4–5 inches in carapace length. The marginals do not flare significantly. This race usually has three toes on each hind foot.

Great Trinity Forest Management Plan

Wildlife Management

Texas River Cooter

(Pseudemys texana)

25. Texas River Cooter

Pseudemys texana

Abundance/Range: Until recently, this pretty river cooter was considered a subspecies of *P. concinna*. This is a common species in suitable aquatic habitats in central and southeastern Texas.

Habitat: The Texas river cooter occurs in vegetated areas of slow-moving rivers as well as in ponds, lakes, oxbows, cattle tanks, and other such permanent bodies of water.

Size: In this moderately domed basking turtle, females may attain 12 inches in length and the males about 9 inches. Hatchlings measure about 1½ inches long.

25a. Texas river cooter, adult

25b. Texas river cooter, hatchling (center turtle)

Identifying features: The green hatchlings and juveniles of the Texas river cooter have a busy pattern of stripes and whorls. The yellow to yellow-orange plastron contains an extensive dark figure that is most prominent anteriorly and along the scute seams. The green head and legs are brightly marked with yellow.

With growth the carapacial ground color dulls to brown or olive black and the pattern becomes at least partially obscured. There are several intricate whorls on the second costal, but the definitive, rearward-facing C so typical of most river cooters may be absent. The rear margin of the carapace is moderately serrate. The marginals may be tinted on the outermost edges with orange. A vertical yellow bar is present in the center of each marginal. Poorly defined ocelli, formed by half-circle meeting half-circle, are present on the upper front and rear of each marginal. Submarginal markings are in the form of well-defined ocelli. This turtle species often becomes darker with advancing age. The plastron is yellow(ish) and may or may not bear remnants of the dark central figure. The shell is deepest at midpoint. Head, neck, and limbs are dark green to black with numerous thin, bright yellow stripes and cheek spots. A vertical yellow bar is usually present near the articulation of the jaw. Other face and neck stripes are diagonal. The limbs and tail are lined with yellow and/or orange (or rose). A medial notch is present in the upper jaw and is flanked on each side by a downward-projecting cusp. Males have long foreclaws.

Similar species: The light whorls on the carapace of the eastern river cooter tend to be heavy and comparatively few. Those of the Texas river cooter are thin and profuse. Both lack a well-defined medial jaw notch and cusps. The red-eared slider has smooth posterior marginals and the namesake red ear marking. Map turtles have a prominent vertebral keel.

Great Trinity Forest Management Plan

Wildlife Management

Yellow-bellied Slider

(Trachemys scripta scripta)

32. Yellow-Bellied Slider

Trachemys scripta scripta

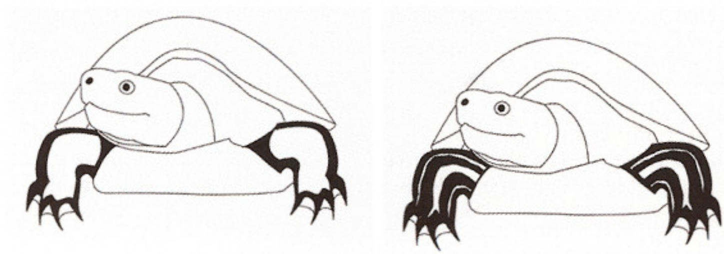
Abundance/Range: This abundant turtle ranges southward in the coastal plain and southern piedmont from southeastern Virginia to northern Florida and its panhandle.

Habitat: The yellow-bellied slider prefers heavily vegetated ponds, lakes, canals, ditches, slowly flowing rivers, and marshes. This turtle and its subspecies may be found in surprisingly small bodies of water.

Size: Typically these pretty turtles attain an adult length of 5–8 inches. Some exceed 10 inches. Adult males are usually somewhat smaller than females. Hatchlings are about 1¼ inches in length.

Identifying features: The coloration of this slider varies with age and other more complex factors. Hatchlings have dark and light markings on a greenish carapace. The green head bears large yellow cheek blotches and diagonal yellow lines from the snout to the chin. The limbs are also greenish and bear several narrow stripes (forelimbs) or spots (rear limbs) of yellow. The skin on each side of the tail is vertically striped with green and yellow.

With growth this turtle darkens to an olive drab or olive black and many of the markings are obscured. Old examples may be almost uniformly black. The yellow facial markings are the last to dull.



Chicken turtle *Yellow-bellied slider*

Turtle leg stripes

32. Yellow-bellied slider, subadult

Juveniles, subadults, and young adults have prominent, dark, rounded markings on the lower surface of the marginals and on the anterior scutes of the plastron. Most sexually mature males have elongated front claws.

Similar species: This is the only one of our turtles to have prominent yellow cheeks. The various river cooters lack strong vertical, light carapacial markings. The various red-bellied cooters have orange rather than yellow vertical markings on their carapace and lack the yellow facial patch. The chicken turtle has an extraordinarily long neck and only a single yellow stripe on the front of its forelimbs.

Additional Subspecies

33. The Red-eared Slider, *Trachemys scripta elegans*, once a turtle of the Mississippi River drainages, is now widespread throughout much of the United States (and indeed, the world). The range extensions are the result of the release or escape of pet turtles. Unwanted pet specimens should be placed in caring foster homes, never released into the wild. Intergrades between this and the yellow-bellied slider or the Cumberland slider, *Trachemys scripta troosti*, are often encountered.

Hatchlings of the red-eared slider have carapaces of green patterned with numerous narrow lighter and darker, primarily vertically oriented lines. The submarginal and plastral scutes are patterned with irregular dark ocelli or spots.

33a. Red-eared slider, adult

33b. Red-eared slider, hatchling from Texas

The green face and limbs are striped with yellow. The very broad red temporal stripe, from which this turtle takes its name, is usually prominently evident but may be relatively narrow, rarely absent, or, in southern Texas, broken into two spots. Males are often duller than females of a similar age and size. Old males can be entirely devoid of pattern and nearly a uniform dark olive to olive black in color. This species attains a carapace length of 7 to nearly 12 inches. Sexually mature males have elongate front claws.

34. Cumberland slider

34. The Cumberland Slider, *Trachemys scripta troosti*, is restricted in distribution to eastern Tennessee and western Virginia. It lacks a yellow cheek patch or broad red ear stripe. Instead, the ear stripe is relatively narrow and orange, yellow, or yellow green. Facial and limb stripes are relatively broad, hence fewer in number than on the yellow-bellied and red-eared sliders. The yellowish plastron bears an ocellus on each of the scutes, but these may obscure with growth. The submarginal spots are narrow. Hatchlings are a rather bright green with dark and light vertically oriented carapacial markings. Larger specimens dull to olive green and melanism may occur.

Great Trinity Forest Management Plan

Wildlife Management

Eastern Yellow-bellied Racer

(Coluber constrictor flaviventris)

M. J. Bowerman

15 **Eastern Yellow-bellied Racer,**
Coluber constrictor flaviventris

115 Eastern Yellow-bellied Racer

Coluber constrictor flaviventris

Nonvenomous If cornered, *C. c. flaviventris* may vibrate its tail, and if restrained it is likely to snap with agility. Compared to even a tiny mammal, however, racers are unable to exert much pressure with their jaws, and pricks or scratches are all that result from a bite.

Abundance The most widely distributed member of its genus, the eastern yellow-bellied racer occupies an enormous range that extends from the northwestern Gulf Coast and arid Trans-Pecos Texas, northwest as far as southern Alberta, and southeast across the Dakotas to Iowa and Missouri.

Size Although reported to reach nearly 6 feet in length, adult *C. c. flaviventris* generally measure between 30 and 54 in.

Habitat Although in the eastern part of its range the eastern yellow-bellied racer generally keeps to wooded cover and traverses overgrown fields mainly on hunting forays, in western parts of its range entire populations live in open grassland. Here, *C. c. flaviventris* is most often found in more vegetated areas such as brush-filled gullies or wooded riparian corridors, however, where it typically shelters under flat rocks, bushes, or clumps of bunchgrass. Derelict buildings with fallen boards and siding constitute another favored microhabitat.

Despite its name, the eastern yellow-bellied racer also inhabits arid deserts. One individual, found near Marathon by the author, was thought to be part of a relict population that had survived in a small mesic refuge remaining from the wetter West Texas of Pleistocene times, until a second specimen was discovered nearby in entirely waterless, rocky desert north of Sanderson.

Such animals have been linked with either the subspecies Mexican racer, *C. c. oaxaca*, or the far western subspecies, *C. c. mormon*, but both these Trans-Pecos individuals were phenotypically perfect eastern yellow-bellied racers, and their presence in the northern Chihuahuan Desert (like the presence of exactly similar individuals also found by the author near Miles City, Montana, in dry, northern Great Plains grassland not far from the Canadian border) simply broadens our perspective of the variety of environments in which this extraordinarily adaptable subspecies can survive.

Prey Despite the name *C. constrictor*, racers are not constrictors. Small prey such as insects are simply snapped up, but when feeding on larger vertebrates—birds, frogs, lizards, other snakes, and rodents are recorded—rather than suffocating their prey by constriction, racers sometimes overpower these creatures by pinning them against the ground with a body coil, then disabling the animal by biting its head.

Like other racers, *C. c. flaviventris* will eat any smaller creature it can capture (the author found a 2-foot-long eastern yellow-bellied racer in a coop housing half-grown chickens far too large for it to swallow), including large insects. Cicadas are important prey for many woodland snakes, and during the periodic simultaneous emergence of tens of thousands of these big insects, eastern yellow-bellied racers feed on them almost exclusively.

Reproduction Egg-laying. With the approach of their early summer parturition, female racers move to denser vegetation than they frequent at other times, subsequently hiding their eggs beneath litter or burying them under a layer of sandy soil. See **Buttermilk Racer**.

Coloring/scale form Adult eastern yellow-bellied racers are a lovely, unmarked blue-gray-green above, with a bright yellow venter. The pale ground-colored young are dorsally blotched with brown, but during their second year, after reaching 16 to 18 inches in length, in an ontogenetic pattern change they start to lose their juvenile coloring, beginning on the tail. There are usually 7 upper labial scales.

Similar snakes In the northeastern portion of its range, the eastern yellow-bellied racer's range abuts that of both the **northern** and **southern black racers (107, 108)**, whose backs are a satiny charcoal gray to jet black, with some white generally visible on the chin and throat. East Texas' subspecies **buttermilk racer (113)** has a darker, gray-blue or gray-green back and sides patterned with profuse off-white scales. In southwestern Texas the eastern yellow-bellied racer's territory overlaps that of the **Mexican racer (116)**, a more southerly and westerly subspecies with a slightly darker back and lighter sides, a greenish-yellow venter, and 8 upper labial scales. (Intergrades between adjoining racer subspecies are common.)

Behavior Racers' comparatively advanced physiology is the primary factor that gives rise to a subtle quality one notices when handling these snakes. Unlike a majority of serpents, racers have an almost mammalian presence: they clearly take note of what is going on around them. A newly captured individual may seem to have settled down passively in one's hands but, in a way not seen among most other serpents, it typically continues to pay attention to its circumstances and, if a chance for escape arises, it is instantly ready to take advantage of the opportunity. See **Southern Black Racer**.

Great Trinity Forest Management Plan

Wildlife Management

Texas Brown Snake

(Storeria dekayi texana)

M. J. Bowerman

21 Texas Brown Snake,
Storeria dekayi texana

21 TEXAS BROWN SNAKE, *Storeria dekayi texana*

Nonvenomous See **Marsh Brown Snake.**

Abundance Common. Texas brown snakes are in no way limited in range to the state for which they are named. In a 200- to 300-mile-wide swath, their range extends from the Rio Grande straight up the Great Plains as far as north-central Minnesota.

In the southern part of this range, Texas brown snakes, as live-bearers, are apparently less susceptible than small egg-laying serpents to attacks by South American fire ants because their newborns seem to be sufficiently vigorous to slip away from these newly introduced insect predators.

Size Most adults are 9 to 12 inches in length; the record is 18 in.

Habitat Along the intricate north/south intersection of North America's eastern woodlands and Great Plains, this animal's macrohabitat includes both riparian bottomland and most open deciduous forest. Texas brown snakes also occur in grassland, including overgrown pastures, but they are not as common there as in places where leaf litter offers cover.

Prey Brown snakes' primary prey is slugs, while earthworms are a secondary food source; arthropods, salamanders, minnows, and newly metamorphosed frogs are also occasionally taken.

Reproduction Live-bearing. Breeding may take place both spring and fall, with spermatozoa from autumn pairings remaining in the female's oviducts until her spring ovulation. Most births occur between mid-June and the first week in August: one central Texas female found in late April devoured slugs and small earthworms until late May, by which time she had become too swollen with developing young to continue feeding. (Brown snakes exhibit the evolutionarily advanced trait of placental nourishment of their offspring during the latter stages of fetal development.)

On June 12 this female gave birth to 11 very active, 4-inch-long young. After their first shed at 9 to 11 days of age, these neonates were offered Q-tips swabbed with the scents of fish, tadpoles, and worms, but only the scent of slugs and snails elicited a feeding response. Other litters have contained 3 to 27 young, measuring from 3½ to 4½ inches.

Coloring/scale form Dark-speckled reddish brown above, with a pale vertebral stripe, adult Texas brown snakes have bold white posterior labial scales. Below and behind the eye the fifth through seventh upper labial scales are blotched with one or more big brown spots; another large brown marking occupies the side of the neck. The creamy venter has a few black dots along its sides. Neonates have dark-speckled gray-brown backs and sides, dark brown heads with little white on their cheeks, and a pale band across their napes. This race's dorsal scales lack apical pits, are arranged in 17 rows, and its anal plate is divided.

Similar snakes Along the eastern periphery of its range the Texas brown snake intergrades with its subspecies, the **midland brown snake (20)**, a race distinguished (often with difficulty) by its often cross-dorsally dark-lined back. Another subspecies, the **marsh brown snake (22)**, has a small, dark horizontal bar that lines its light-hued temporal and postocular scales and generally unmarked pale labial scales.

Behavior See **Midland Brown Snake.**

Behavior Because midland brown snakes find favorable conditions in the soft soil of well-watered suburban yards, they are sometimes found while gardening. Although generally secretive little animals, during cool, damp weather they may move about in the open, even in daylight; in the hottest months brown snakes are nocturnal.

Great Trinity Forest Management Plan

Wildlife Management

Texas Rat Snake

(Elaphe obsoleta lindheimerii)

M.J. Bowerman

138a Texas Rat Snake,
Elaphe obsoleta lindheimerii

M. J. Bowerman

138b Texas Rat Snake,
Elaphe obsoleta lindheimerii (juvenile)

TEXAS RAT SNAKE, *Elaphe obsoleta lindheimerii*

Nonvenomous Texas rat snakes are vigorous in their own defense and if threatened often make several mostly bluffing, open-mouthed strikes. Pressed further, *E. o. lindheimerii* may defecate in fear, emit musk from its cloacal glands, and ultimately, bite—though the pressure of its jaws is slight and only scratches usually result.

Abundance Very common. One of the handful of truly abundant large terrestrial serpents, the Texas rat snake is the long, brown-mottled snake that most often appears in suburban neighborhoods throughout the eastern ⅔ of Texas and the southern ⅔ of Louisiana. It is likely to be found high in trees or, in human-populated areas, hidden in barns, henhouses, abandoned buildings and machinery. After the grayish young hatch in late summer, they are often found around both rural and suburban houses and, like the adults, nip when picked up.

Size Adult Texas rat snakes are slender but long, averaging 42 to 72 inches—dimensions which in Louisiana has earned *E. o. lindheimerii* the nickname "piney woods python." The record is just over 7 feet.

Habitat Abundant in both deciduous woods and pastureland, this reptile is named for pioneer naturalist Ferdinand Jacob Lindheimer, who collected the type specimen near his home in New Braunfels, Texas. This westernmost race of *Elaphe obsoleta* also occurs in almost every terrestrial and aquatic-margin environment from upland pine/hardwood forest to coastal prairie marsh.

Prey Both juvenile and adult Texas rat snakes feed almost entirely on warm-blooded prey, especially birds and their nestlings—on which *E. o. lindheimerii* is a major predator. (A flock of blue jays and other passerines screaming at a Texas rat snake coiled high in the branches is a common woodland sight.)

Also called "chicken snake" for its attraction to the rodents (and sometimes eggs and chicks) to be found in henhouses, *E. o. lindheimerii* is equally likely to be seen by the usually shocked residents of wooded subdivisions who set out cage birds on their patios. Larger prey such as small mammals are overpowered by constriction.

Reproduction Egg-laying. Hatchling Texas rat snakes are 12 to 14 inches long, with lead-gray crowns striped by a pair of solid chocolate lines that form a forward-facing spearpoint. Another chocolate-colored band masks the eyes and extends rearward only as far as the posterior upper labial scales. Juveniles' backs have a pale gray ground color, boldly patterned with darker-edged, irregularly shaped brown dorsal and lateral blotches which enlarge and, along with their ground color, darken as they mature.

Coloring/scale form Adult Texas rat snakes' large, dark brown rectangular vertebral blotches are separated by smaller, yellowish brown transverse areas about 4 scale rows in width; reddish skin may be evident on the sides of the neck. Older adults are darker in color. The pale venter is blotched with dark squares partially obscured by a grayish overwash, while the underside of the tail tip is usually solid gray. Of the 27 midbody rows of dorsal scales, those along the spine are most strongly keeled.

Similar snakes To the northeast, the subspecies **black rat snake (134)** is almost entirely an unmarked black above, with only traces of dark dorsal blotches; its chin and forebelly are off-white. Another rat snake, formerly classified as a subspecies but now accorded full species status, the **Baird's rat snakes (139)**, is faintly striped above and lacks dorsal blotches; juveniles are grayer than young Texas rat snakes, with dark transverse vertebral bars. The similar-looking juvenile **Great Plains rat snake (141)** has a black-edged brown V on its pale crown. Another dark-edged brown band crosses its snout, masks its eyes, and extends posteriorly onto its neck, while a pale subcaudal midventral stripe is centered between dark distal borders. The **prairie kingsnake (147)** has smooth scales and an undivided anal plate.

Behavior The Texas rat snake's wiry musculature and sharp-edged belly scales make it an agile climber, but it also patrols creek banks from the water, and has been captured swimming across the middle of large lakes. See **Gray Rat Snake.**

Great Trinity Forest Management Plan

Wildlife Management

Western Cottonmouth

(Agkistrodon piscivorus leucostoma)

M.J. Bowerman

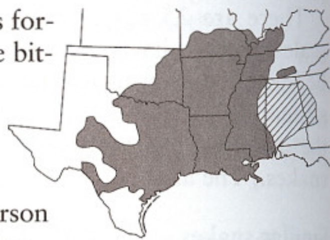
181a **Western Cottonmouth,**
Agkistrodon piscivorus leucostoma

M.J. Bowerman

181b **Western Cottonmouth,**
Agkistrodon piscivorus leucostoma (juvenile)

181 Western Cottonmouth

Agkistrodon piscivorus leucostoma



Venomous Despite the cottonmouth's formidable reputation, very few people are bitten by this reptile, and even fewer are seriously injured: only about 7 percent of Texas' snakebites involve cottonmouths, and throughout the United States the mortality rate is less than 1 person per year. Envenomation by *Agkistrodon piscivorus* may result in substantial tissue death, however, because these big aquatic vipers have up to ⅝-inch-long fangs and venom-storage lumens which, from the largest individuals, can yield hundreds of mg., dry weight, of venom. While its toxins are less potent than those of most large *Crotalus*-genus rattlesnakes—Sherman Minton estimates the lethal dose for a healthy human adult as about 150 mg—the hemorrhagic effects of cottonmouth venom are pronounced. See **Venom Potency Table.**

Abundance Locally very common. Although the majority of presumed "cottonmouth" sightings are actually of *natricine* water snakes, western cottonmouths are extremely numerous in some places, especially on the Gulf coastal plain. Near Sinton, Texas, as well as 100 miles to the north, as on ricefield levees around Egypt, the author has seen a basking cottonmouth every few hundred yards. Dense populations of this big pitviper can even make themselves known by scent: in the still air of forest-enclosed woodland ponds in East Texas the musky smell of *Agkistrodon piscivorus* can sometimes be detected.

Size The record *A. p. leucostoma*, taken on East Texas' Neches River by George O. Miller, was a fraction of an inch over 5 feet in length. Most western cottonmouths are much smaller, however: of 306 recorded individuals, only a few males—which grow larger than females—were longer than 3 feet, and the great majority measured between 20 and 30 inches.

Habitat Although western cottonmouths are generally found within ½ mile of permanent water, they are not limited to aquatic environments (all cottonmouth races favor leutic microhabitats primarily because of the more plentiful prey and better cover available there, but they do quite well in entirely dry milieus). Dry forest, grassland, and even cornfields are also occupied; in spring, a flooded prairie is a prime foraging site. Salt marshes and the low-lying saline barrier islands bordering the Gulf coast also constitute good territory for western cottonmouths, yet the density of *A. p. leucostoma* populations tends to vary widely, with large areas of apparently perfect wetland habitat being almost entirely devoid of these reptiles.

Prey The western cottonmouth may feed on any vertebrate small enough to swallow. Frogs are probably this pitviper's most frequent prey, but *A. p. leucostoma* (its Greek-derived subspecies name means "white-mouthed") is an indiscriminate feeder whose diet alters with the availability of different food species. Water birds, smaller snakes—including copperheads and even other cottonmouths—are also reported, as are a variety of fish species, although game fish are generally too fast for cottonmouths to capture. Like other aquatic serpents, *A. piscivorus* also feeds on carrion and is consequently drawn to wounded and dying fish dangling from fishermen's stringers.

Reproduction Live-bearing. Reproduction follows the usual viperid pattern of slow growth, delayed maturation, and low reproductive frequency. But the enhanced foraging opportunities afforded by their rich aquatic habitat give female cottonmouths a better chance than terrestrial vipers of acquiring the increased body fat necessary for successful pregnancy. (Unlike terrestrial viperids, many of which require two years' hunting to acquire enough fatty tissue to nourish their large, well-developed young, female *A. piscivorus* may breed every year.)

During early spring courtship adult male cottonmouths typically follow a female's pheromone scent trail, sometimes even across lily pads. If they encounter another male engaged in the same pursuit, dominance behavior is likely to ensue, with each combatant attempting to force down the other's foreparts. Pairing initially involves tongue-flicking of the female's back by the male, followed by rubbing his chin along her spine, after which copulation may last several hours.

Because gestation among snakes is not as uniformly timed as among birds and mammals, fertilization may be delayed for weeks while sperm remain viable in the cloaca. Up to several months after copulation, the 8- to 11-inch-long young are born during August, September, and early October. They are so stoutly proportioned that gravid females bear only 3 to 12 offspring per litter (while similarly sized water snakes typically deposit dozens of much more slender young).

Newborn western cottonmouths are both more brownish and more clearly patterned than adults, with dark dorsal bars and lateral blotches. Their tails have gray-green tips which, in a predatory technique shared with their relatives the copperheads, are instinctively flicked back and forth in the excitement of seeing prey, thus unconsciously imitating the movements of a worm or caterpillar and reportedly sometimes luring small frogs and toads within striking range.

Coloring/scale form See **Florida Cottonmouth**. Adult western cottonmouths are dark gray-brown, with broad, dimly defined lateral banding. (Some individuals' dull dorsal coloring results from a film of water-deposited sediment and algae: clean-water-living cottonmouths show more distinct patterning.) Very old cottonmouths, however, may be entirely dark gray or black.

In daylight, the pupils of the large, grayish eyes are vertical black slits easily discernible from a safe distance; at night in the beam of a flashlight they are oval or rounded for the few moments it takes them to close against the glare. Definitive but less evident is the dark orifice of the heat-sensing pit located between the eye and nostril and the pronounced taper from the thick posterior trunk to the cottonmouth's attenuated little tail; especially among females the tail seems out of proportion to the thickset trunk. The male's tail contains its hemipene and is somewhat larger.

The keeled dorsal scales occur in 25 rows at midbody, while the subcaudal scutes display a unique pattern by which even from their shed skins *Agkistrodon* can be identified: behind the undivided anal plate a single row of belly-wide scale plates occupies the under-tail tip.

Similar snakes The dark, heavy bodies and aquatic habitat of **large water snakes (64, 68–71, 74–76, 79–81, 90, 92)** often cause them to be mistaken for the western cottonmouth. All water snakes lack the cottonmouth's heat-sensing pit between eye and nostril, however, and have clearly visible round pupils.

Agkistrodon piscivorus also behaves differently from water snakes, which neither gape in threat nor vibrate their tails in agitation. Also unlike water snakes, the cottonmouth swims in a leisurely way, its whole body floating buoyantly, with the head held high. Water snakes swim by squirming rapidly along, their bodies drooping below the surface when they stop. Juvenile **copperheads (174, 176, 177)** are lighter brown and have dark-edged beige cheeks unlike the cottonmouth's dark labial scales.

Behavior The most widespread story about the cottonmouth concerns the water-skier purportedly killed by a flurry of bites after tumbling into a "nest" of these reptiles. For years various re-tellings of this fictitious event have circulated in boating circles, and an even more absurd fantasy about a cowboy killed by western cottonmouths while crossing a river on horseback appeared in the television special *Lonesome Dove*.

All such episodes are untrue: no water-skier or river-fording horseman has ever suffered multiple *A. piscivorus* envenomation. These scary myths originate in people's observations of the large number of harmless water snakes that, during late summer, become concentrated in drying creeks and stock tanks, where they are mistaken for nests of cottonmouths.

Cottonmouths do not "nest," however, and packed groups would last no longer than it took the larger *A. piscivorus* to swallow their smaller relatives. Further, in the water cottonmouths quickly dive and flee even when approached stealthily—much less when confronted with the churning bow wave of a 1,000-pound mustang. On land, an occasional western cottonmouth will hold its ground and gape open-mouthed, but none attack en masse. (In fact, the cottonmouth's notorious gape is actually a comparatively passive defense gesture, for such wide-jawed *A. piscivorus* often fail to strike even when prodded with a boot.)

Great Trinity Forest Management Plan

Wildlife Management

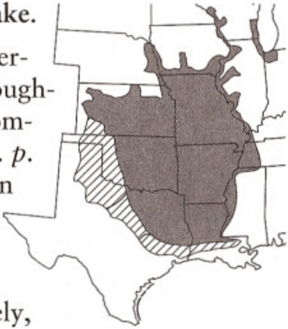
Western Ribbon Snake

(Thamnophis proximus proximus)

58 **Western Ribbon Snake,**
Thamnophis proximus proximus

58 WESTERN RIBBON SNAKE

Thamnophis proximus proximus



Nonvenomous See **Red-striped Ribbon Snake.**

Abundance Western ribbon snakes are generally common in areas of suitable habitat throughout both the southern Great Plains and its complex interface with the eastern woodlands. *T. p. proximus* inhabits a long sweep of this terrain stretching from central Louisiana and northeastern Texas to northern Kansas and Missouri, then upstream along the Missouri and Mississippi River corridors to, respectively, northern Nebraska and southern Minnesota; other subspecies range as far south as Costa Rica.

Size Adults are 20 to 34 inches long, with such slender bodies that 3 female western ribbon snakes between 27 and 34 inches in length—as with all *Thamnophis*, females are the larger gender—averaged less than 6 ounces in weight.

Habitat As the old forest of the eastern U.S. woodlands thins toward the open country of the plains, agricultural lands now prevail, but these are not as hostile to ribbon snakes as to larger snake species. The drainage ditches bordering crop fields offer an approximation of ribbon snakes' natural creekside microenvironment, and *T. p. proximus* may occur near any strip of fresh water—natural or man-made—with vegetative cover along its banks. It is also often found in arid brush country, but seldom far from a source of water.

Prey Western ribbon snakes' prey varies with the seasons: 92 percent of the stomach contents of one central Texas sample trapped during late spring consisted of tadpoles. At other times frogs and toads (whose digitaloid skin toxins garter snakes are metabolically equipped to digest), lizards, and small fish may be this snake's principal prey. Besides mammalian and avian carnivores, ribbon snakes are themselves devoured by big, fast-moving snakes like racers and coachwhips.

Reproduction Live-bearing. One female *T. p. proximus* captured near Stanford, Oklahoma, gave birth to 21 young on Aug. 8, while three litters from northeast Texas were deposited July 10 and 18, and Aug. 20.

Of these three, the two smaller females each gave birth to 18 young, the larger one to 23. All the neonates were about the same size: between 9½ and 10 inches in length, slimmer than a pencil at midbody, and about 1/10 ounce in weight.

As with most snake species, mortality among first- and second-year juveniles is high. Donald Clark (1974) reports heavy winter die-offs among juvenile western ribbon snakes, presumably because their smaller ratio of bulk-to-surface area renders them more vulnerable to desiccation during their critical November-through-February brumation period.

Among Clark's East Texas population, sufficient rainfall before and during denning appeared to be the primary factor determining survival of juvenile *T. p. proximus*, for dry autumn weather limited the abundance of small frogs and resulted in low fat levels among the young about to enter winter dormancy. Little precipitation later in the year, combined with very cold winter weather, then resulted in an estimated mortality of 74% of this vulnerable age group during brumation.

Coloring/scale form The western ribbon snake's unmarked dark gray-brown dorsum is split by a broad orange vertebral stripe. Like that of all ribbon snakes, its yellowish lateral stripe occupies the third and fourth scale rows above its yellowish-green venter. Its white upper labial scales are unmarked, although the lips, lateral stripe, and belly of individuals living north and east of Dallas often have a bluish cast. Two tiny white dashes punctuate the rear of its blackish crown and a rearward-curved white spot occurs just in front of each eye. The dorsal scales are arranged in 19 rows at midbody and the anal plate is undivided.

Similar snakes Of the several races with which the western ribbon snake intergrades, the **Gulf Coast ribbon snake** (60) typically has a brownish- to olive-green back and sides and an olive-tan to dull gold vertebral stripe, and the **red-striped ribbon snake** (59) has a dark gray back, a wine-red vertebral stripe, and gray-green lower sides. The **arid land ribbon snake** (61) usually has a gray-brown back (although individuals from the Canadian and Cimarron River drainages sometimes have a darker ground color), with both a distinctive thin black ventrolateral seam and a broad orange vertebral stripe that lightens to gold on the nape.

Behavior During late August and September newborn ribbon snakes can sometimes be found sheltering in tall creekside grass or under planks; in taller brush of lake and stream shorelines these juveniles are sometimes somewhat arboreal; near the Red River nine small western ribbon snakes were observed basking the branches of a brush-filled gully.

Literature Cited

Allen, A.W. 1982. Habitat Suitability Index Models: Eastern cottontail. U.S. Fish and Wildlife Service. FWS/OBS-82/10.66.

Allen, A.W. 1982. Habitat Suitability Index Models: Fox squirrel. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.18.

Allen, A.W. 1987. Habitat Suitability Index Models: Barred Owl. U.S. Fish and Wildlife Service, Biological Report 82(10.143).

Barry, D. 2000. Thresholds in Avian Communities at Multiple Scales: Relationships Between Birds, Forests Habitats and Landscapes in the Ray Roberts Greenbelt, Denton, Texas. Dissertation, University of North Texas, Denton, Texas, USA.

Bartlett, R.D. and P.P. Bartlett. 2006. Guide and Reference to the Crocodilians, Turtles and Lizards of Eastern and Central North America (North of Mexico). University of Florida Press, Gainesville, Florida, USA.

Bowen, L.T., C.E. Moorman and J.C. Kilgo. 2007. Seasonal bird use of canopy gaps in a bottomland forest. The Wilson Journal of Ornithology, Vol. 119(1): 77-88. <http://www.treesearch.fs.fed.us/pubs/26694> Accessed 1 Aug 2007.

Brittingham, M.C. and C.A. DeLong. 1998. Management Practices for Enhancing Wildlife Habitat. Pennsylvania State College of Agricultural Sciences, Cooperative Extension. <http://pubs.cas.psu.edu/FreePubs/pdfs/uh107.pdf > Accessed 21 Aug 2007.

Brown, Kirby, D. Rideout, M. Wagner, J. Dillard, L. Campbell and L. McMurry. 2007. Wildlife Management Activities and Practices Comprehensive Wildlife Management Planning Guidelines for the Post Oak Savannah and Blackland Prairie Ecological Regions. Texas Parks and Wildlife PWD BK W7000 0789 <http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_bk_w7000_0789_main.pdf> Accessed 1 Nov 2007

Cantrell, R.L., W.G. Minser and M.M. King. Trees for Wildlife. University of Tennessee Agricultural Extension Service PB1446. <http://www.utextension.utk.edu/publications/pbfiles/pb1446.pdf> Accessed 15 Aug 2007.

Castleberry, S.B., W.M. Ford, K.V. Miller and W.P. Smith. 1999. White-tailed Deer Browse Preferences in a Southern Bottomland Hardwood Forest. Journal of Applied Forestry 23(2):78-82.

Conner, R.N. and D. Saenz. 1996. Woodpecker Excavation and Use of Cavities in Polystyrene Snags. Wilson Bull., 108(3): 449-456. <http://www.treesearch.fs.fed.us/pubs/1300> Accessed 1 Aug 2007.

Cook, R.L. 1992. Learn About Whitetails. Texas Parks and Wildlife PWD-LF-W7000-0007-2/93. <http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_lf_w7000_0007.pdf > Accessed 17 Dec 2007.

Creacy, G. 2006. Deer Management within Suburban Areas. Texas Parks and Wildlife PWD BK W7000-1197. <http://www.tpwd.state.tx.us/huntwild/wild/game_management/overabundant_deer/ > Accessed 17 Dec 2007.

Davis W.B. and D.J. Schmidly. 1997. The Mammals of Texas- Online Edition. Texas Tech University. <http://www.nsrl.ttu.edu/tmot1/Default.htm> Accessed 1 Dec 2007.

Demers, C., A. Long and C. Latt. 1999. Establishing and Maintaining Wildlife Food Sources. University of Florida/Institute of Food and Agricultural Sciences (IFAS) Extension SS-FOR-12. <http://edis.ifas.ufl.edu/FR062> Accessed 18 Sept 2007.

Dillard, J. 2000. Herd Composition: An Essential Element of White-tailed Deer Population and Harvest Management in the Cross-Timbers of North Texas. Texas Parks and Wildlife PWD RP W7000-1134. <http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_rp_w7000_1134.pdf > Accessed 17 Dec 2007.

Dillard, J. 2000. Guidelines for White-tailed Deer Management in the Cross-Timbers and Prairies Region of North Texas. Texas Parks and Wildlife PWD RP W7000-1133. <http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_rp_w7000_1133.pdf> Accessed 17 Dec 2007.

Fisher, C.D. 1972. Summer Birds and Mammals Inhabiting the Trinity River. Pages 306-344 *in* Fisher C.D., D.D. Hall, H.L. Jones, J.D. McCullough and A.P. McDonald. A Survey of the Environmental and Cultural Resources of the Trinity River. Vol. 2. Stephen F. Austin State University, Nacogdoches, Texas, USA.

Freeman, B. 2003. Birds of the Oaks and Prairies and Osage Plains of Texas: A Field Checklist. Texas Parks and Wildlife PWD BK W7000-869. <http://www.tpwd.state.tx.us/huntwild/wild/birding/pif/ecoregions/#osage_oaks> Accessed 10 Sept 2007.

Garrett, J.M. and D.G. Barker. 1987. A Field Guide to Reptiles and Amphibians of Texas. Texas Monthly Press, Austin, Texas, USA.

Graczyk, M. 2008. Texas Researchers Developing 'Pill' for Wild Hogs: Texas A&M researchers working on contraception to thin herds of destructive wild hogs. ABC News <http://abcnews.go.com/Technology/wireStory?id=4883234> Accessed 5 May 2008.

Grondahl, C. and J. Dockter. No Date. Building Nest Structures, Feeders, and Photo Blinds for North Dakota Wildlife. North Dakota Game and Fish Department, Northern Prairie Wildlife Research Center Online <http://www.npwrc.usgs.gov/resource/wildlife/ndblinds/index.htm > Accessed 29 Aug 2007.

Hailey, T.L. 1979. Basics of Brush Management for White-tailed Deer Production. Texas Parks and Wildlife PWD-BK-7100-12/88. <http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_bk_w7000_0035.pdf > Accessed 17 Dec 2007.

Harper, C.A. 2004. Growing and Managing Successful Food Plots for Wildlife in the Mid-south. University of Tennessee Extension PB1743. <http://www.utextension.utk.edu/publications/pbfiles/PB1743.pdf > Accessed 1 Aug 2007.

Halls, L.K. 1973. Flowering and Fruiting of Southern Browse Species. Res. Pap. SO-90. USDA Forest Service, Southern Forest Experiment Station. <http://www.treesearch.fs.fed.us/pubs/25670> Accessed 1 Aug 2007.

Higginbotham, B.J. 1996. Texas Farm Pond Management Calendar. Texas Cooperative Extension, the Texas A&M University System. <http://wildlife.tamu.edu/publications/TAEXPonds/1002a.pdf> Accessed 1 Aug 2007.

Hoffman, K.W. 2001. Riparian Forest Width and the Avian Community in a Greenbelt Corridor Setting. Thesis, University of North Texas, Denton, Texas, USA.

Hygnstrom, S.E., R.M. Timm, G. E. Larson, editors. 1994. Prevention and Control of Wildlife Damage. University of Nebraska-Lincoln. 2 vols. <http://icwdm.org/handbook/index.asp> Accessed 6 Dec 2007.

Kopachena, J.G. and C.J. Crist. 2000. Macro-habitat Features Associated with Painted and Indigo Buntings in Northeast Texas. Wilson Bulletin 112(1): 108-114.

Krueger, M. and J. Dillard. 2000. Developing a Deer Management Plan. Texas Parks and Wildlife PWD RP W7000-1132. <http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_rp_w7000_1132.pdf> Accessed 17 Dec 2007.

Lock, J.T. 1996. Management of Recreational Fish Ponds in Texas. Texas Cooperative Extension B-213, the Texas A&M University System. <http://wildlife.tamu.edu/publications/TAEXPonds/213b.pdf> Accessed 1 Aug 2007.

Lockwood, M.W. 2007. Basic Texas Birds: A Field Guide. University of Texas Press, Austin, Texas, USA.

Lower Mississippi Valley Joint Venture Forest Resource Conservation Working Group. 2007. Restoration, Management and Monitoring of Forest Resources in the Mississippi Alluvial Valley: Recommendations for Enhancing Wildlife Habitat. Edited by R. Wilson, K. Ribbeck, S. King and D. Twedt. Vicksburg, Mississippi, USA.

Lyons, R.K., T.F. Ginnett and R.B. Taylor. 1999. Woody Plants and Wildlife: Brush Sculpting in South Texas and the Edwards Plateau. Texas Cooperative Extension L-5332, the Texas A&M University System. <http://tcebookstore.org/tmppdfs/21734977-L5332.pdf> Accessed 25 Oct 2007

MacGowan, B.J. 2003. Designing Hardwood Tree Planting for Wildlife. USDA Forest Service North Central Research Station and Purdue University Department of Forestry and Natural Resources. FNR-213. <http://www.agriculture.purdue.edu/fnr/HTIRC/documents/FNR-213.pdf> Accessed 1 Oct 2007.

Manning, R.W. and C. Jones. 1998. Annotated Checklist of Recent Land Mammals of Texas, 1998. Museum of Texas Tech University Occasional Papers, Number 182. <http://www.nsrl.ttu.edu/publications/opapers/ops/op182.pdf> Accessed 8 Nov 2007.

Mapston, M.E. 2004. Feral Hogs in Texas. Texas Cooperative Extension B-6149, the Texas A&M University System. <http://wildlife.tamu.edu/publications/B6149FeralHogs_low.pdf> Accessed 8 Nov 2007.

Marks, R. 2006. Importance of Disturbance in Habitat Management. Natural Resources Conservation Service and Wildlife Habitat Council, Fish and Wildlife Habitat Management Leaflet Number 37. <http://www.whmi.nrcs.usda.gov/technical/leaflet.htm> Accessed 29 Aug 2007.

May, H.L. 2001. Artificial Nesting Structures. Natural Resources Conservation Service Wildlife Habitat Management Institute and Wildlife Habitat Council, Fish and Wildlife Habitat Management Leaflet Number 20. <http://www.whmi.nrcs.usda.gov/technical/leaflet.htm> Accessed 29 Aug 2007.

May, H.L. and M.B. Ryan. 2002. Integrated Pest Management (IPM) and Wildlife. Natural Resources Conservation Service Wildlife Habitat Management Institute and Wildlife Habitat Council, Fish and Wildlife Habitat Management Leaflet Number 24. <http://www.whmi.nrcs.usda.gov/technical/leaflet.htm> Accessed 29 Aug 2007.

May, H.L. 2002. Managing Forests for Fish and Wildlife. Natural Resources Conservation Service Wildlife Habitat Management Institute and Wildlife Habitat Council, Fish and Wildlife Habitat Management Leaflet Number 18. <http://www.whmi.nrcs.usda.gov/technical/leaflet.htm> Accessed 29 Aug 2007.

North Central Texas Birds. 2005. Birds of White Rock Lake and Vicinity. <http://www.nctexasbirds.com/wr-lake.htm> Accessed 20 Feb 2008.

North Central Texas Birds. 2007. Dallas County 2007 Christmas Bird Count. <http://www.nctexasbirds.com/07-08xmas/DallasCBCJP2007.htm> Accessed 20 Feb 2008.

Orrock, J.L., J.F. Pagels, W.J. McShea and E.K. Harper. 2000. Predicting Presence and Abundance of a Small Mammal Species: The Effect of Scale and Resolution. Ecological Applications 10(5): 1356-1366.

Sallabanks, R., J.R. Walters and J.A. Collazo. 2000. Breeding Bird Abundance in Bottomland Hardwood Forests: Habitat, Edge and Patch Size Effects. The Condor 102:748-758.

Scharfer, J. and S. Miller. 2001. Bird Nighttime Roosts. University of Florida/Institute of Food and Agricultural Sciences (IFAS) Extension SS-WIS-53. <http://edis.ifas.ufl.edu/UW087> Accessed 18 Oct 2007.

Schroeder, R.L. 1983. Habitat Suitability Index Models: Black-capped Chickadee. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.37.

Schroeder, R.L., and P.J. Sousa. 1982. Habitat Suitability Index Models: Eastern Meadowlark.

U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.29.

Shackelford, C.E., E.R. Rozenburg, W.C. Hunter and M.W. Lockwood. 2005. Migration and the Migratory Birds of Texas: Who They Are and Where They Are Going. Texas Parks and Wildlife PWD BK W7000-511. <http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_bk_w7000_0511.pdf > Accessed 10 Sept 2007.

Shult, M.J. and B. Armstrong. 1999. Deer Census Techniques. Texas Parks and Wildlife PWD BK W7000-083. <http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_bk_w7000_0083.pdf > Accessed 17 Dec 2007.

Sousa, P.J. 1987. Habitat Suitability Index Models: Hairy Woodpecker. U.S. Fish and Wildlife Service, Biological Report 82(10.146).

Sousa, P.J., and A.H. Farmer. 1983. Habitat Suitability Index Models: Wood Duck. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.43.

Telfari II, R.C., B.C. Thompson and L. Tschirhart. 2000. Nuisance Heronries in Texas: Characteristics and Management, Second Edition. Texas Parks and Wildlife PWD BK W7000 0134 <http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_bk_w7000_0134.pdf > Accessed 20 Nov 2007.

Tennant, A. 2003. Snakes of North America: Eastern and Central Regions. Lone Star Books, Lanham, Maryland, USA.

Texas Parks and Wildlife. 1999. Controlling Brown-headed Cowbirds. PWD BR W7000 0514 <http://www.tpwd.state.tx.us/huntwild/wild/birding/birding_management/index.phtml> Accessed 10 Sept 2007.

Texas Parks and Wildlife. 2007. Fishes Found in Texas Fresh Waters. <http://www.tpwd.state.tx.us/landwater/water/aquaticspecies/inland.phtml> Accessed 20 Feb 2008.

U.S. Fish and Wildlife Service. 1980. Habitat Suitability Index Models: Raccoon. U.S. Department of the Interior, Fish and Wildlife Service. Review Copy. 108 pp.

U.S. Fish and Wildlife Service. 1980. Habitat Suitability Index Models: Red-Tailed Hawk. U.S. Department of the Interior, Fish and Wildlife Service. Review Copy. 173 pp.

University of Texas. 2000. Herps of Texas. <http://www.zo.utexas.edu/research/txherps/> Accessed 1 Jan 2008.

Wagner, M.. 2000. Brush Sculpting for Nongame Birds. Texas Parks and Wildlife PWD RP W7000-1147. <http://www.tpwd.state.tx.us/huntwild/wild/birding/birding_management/index.phtml> Accessed 10 Sept 2007.