WILDLIFE-HABITAT RELATIONSHIP MODEL,

AVIAN COMMUNITY STRUCTURE, AND

SHOREBIRD HABITAT USE IN

SOUTH-CENTRAL

OKLAHOMA

BY

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Bachelor of Science

University of Maine

Orono, Maine

1995

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 1998

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Thesis Approved:

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ACKNOWLEDGMENTS

I wish to express my appreciation to my major advisor, Dr. David M. Leslie, Jr., for the guidance and effort he provided. I am also very grateful to my committee members Drs. William L. Fisher and Eric Hellgren for their valuable contributions to this thesis.

I am grateful to the Trust for Public Land for their financial support. I am very thankful to the Oklahoma Cooperative Fish and Wildlife Research Unit (Oklahoma Department of Wildlife Conservation, Oklahoma State University, U.S. Geological Survey Biological Resource Division, and Wildlife Management Institute, cooperating) for the support they have given through their resources and personnel.

I am thankful to the entire staff at Tishomingo National Wildlife Refuge. They provided help and knowledge that proved to be very useful in my studies. I would like to thank Mark Gregory, Joe Sieg, and Dr. David Waits of Oklahoma State University. They all helped with theoretical and technical issues regarding GIS. I would like to acknowledge everyone who helped me in the field. It wasn't easy work and I was lucky to have people who were willing to work hard.

None of this work could have been possible if it weren't for each member of my family; they have always supported me each in their own way. A special thanks to Mom, Dad, and Andy. This accomplishment is theirs as well as mine.

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CHAPTER I

INTRODUCTION

This thesis is composed of 3 manuscripts written in formats suitable for submission to selected scientific journals. Each manuscript is complete without supporting materials. Chapter II, "GIS-based wildlife-habitat relationship model for Tishomingo National Wildlife Refuge," is written in the format of Environmental Management. Chapter III, "Avian community structure of the dissected coastal plain along the red river, Oklahoma," is written in the format of The Southwestern Naturalist. Chapter IV, "Habitat use of shorebirds at a stopover site in the southern great plains," is written in the format of the Journal of Field Ornithology.

CHAPTER II

GIS-BASED WILDLIFE-HABITAT RELATIONSHIP MODEL FOR TISHOMINGO NATIONAL WILDLIFE REFUGE

Abstract

We evaluated the adequacy of wildlife-habitat relationship (WHR) models for predicting the occurrence of terrestrial vertebrates for Tishomingo National Wildlife Refuge (NWR), a small (6,669 ha) refuge in south-central Oklahoma. Species presence and distribution in the refuge were predicted by searching scientific literature and creating habitat associations for all species with a GIS habitat map of the refuge. We compared predicted and inventoried terrestrial vertebrates using data collected in the field. Omission errors, commission errors, and accuracy estimates were calculated for each taxonomic group and for each taxonomic group within 3 habitat types. We used Chi-square analysis to determine if there was a statistical difference between predicted and inventoried species. A total of 274 vertebrate species was predicted to be at Tishomingo NWR, but we inventoried only 156 species. Overall, omission errors were lower than commission errors for taxonomic groups and habitat types. There was a difference between predicted number of species in all taxonomic groups and habitat types and those that were inventoried ($\chi^2 = 41.57$, df = 11, $P < 0.0001$). Our results indicate that our landscape-level model is inadequate for predicting habitat-specific distributions but adequate for presence predictions by refuge managers. Our study indicates that WHR models created for smaller areas are not necessarily as accurate as larger-scale models.

Key Words: terrestrial, vertebrates, wildlife-habitat relationship model, management.

Wildlife-habitat relationship (WHR) models have been used to predict presence of terrestrial vertebrate species in a particular landscape or habitat (Dendon and others 1986, Timothy and Stauffer 1991, Block and others 1994, and Edwards and others 1996). Perhaps the best known example of a WHR model is Gap Analysis (Scott and others 1993). Gap Analysis identifies "gaps" in protection of biological diversity. Because Gap Analysis is conducted initially at the statewide level, studies differ in scale; however they have similar methods. All studies use vegetative landcover to predict presence of vertebrate species. Some studies also use ancillary data (e.g., hydrography, soils, elevation, etc.) to refine their predictions (Shaw and

Atkinson 1990, Pereira and Itami 1991, and Clark and others 1993).

Wildlife-habitat relation (WHR) models have been enhanced with the emergence of Geographic Information Systems (GIS) technology. A GIS enters, stores, manipulates, analyzes, and displays a variety of geographic or spatial data (Congalton and Green 1992). GIS can provide a spatial reference for WHR models by applying the model to land cover polygons of a vegetation map (Scott and others 1993).

Wildlife-habitat relation models have many applications for resource managers. Harris and others (1995) used a spatial model to assist resource managers identify conflict areas between humans and mountain sheep (Ovis canadensis). Chow and others (1994) used wildlife predictions with GIS to include wildlife considerations in land use planning. Brown and others (1994) used a GIS decision support system to analyze issues in wildlife use, recreational use, and timber management in 2 national parks in British Columbia. Avery and van Riper (1990) suggested that a WHR model provides resource managers with current information about distributions of wildlife and capabilities of habitats to support wildlife. Airola (1988) reported some advantages of WHR models: 1) they encourage consideration of all species in management; 2) they can assess effects of habitat alteration; 3) they provide access to information and permit easy updating; and 4) they enable managers to focus on species that need special attention.

The purpose of this study was to develop a WHR model for Tishomingo National Wildlife Refuge (NWR) in south-central Oklahoma. The utility of a WHR model depends on how well it represents nature. The best way to evaluate the predictive accuracy of a WHR model is to compare model predictions to data collected in the field (Timothy and Stauffer 1991, Avery and van Riper 1990, Scott and others 1993, Csuti and Crist 1998). Model testing will provide information about 1) model performance and reliability and 2) a means for model improvement of the applied and other models (Schamberger and O'Neil 1986). We compared results of a WHR model developed for Tishomingo NWR with data collected from the refuge to assess the accuracy of the model.

Study Site

The study was conducted on the 6,669-ha Tishomingo NWR located in south-central Oklahoma (34°10'N, 96°40'W). The refuge consisted of the Midgrass Eroded Plains Vegetation Type and Post Oak-Blackjack Forest Type (Duck and Fletcher, 1943). Principal woody species were blackjack oak (*Quercus marilandica*), winged elm (*Ulmus alata*), osage-orange

(Maclura pomifera), chickasaw plum (Prunus angustifolia), and persimmon (Diospyros virginiana). Bottomlands were dense stands of willow (Salix spp.) with some cottonwood (Populus deltoides). Dominant grasses included little bluestem (Andropogon scoparius), broomsedge bluestem (A. virginicus), and Indian grass (Sorghastrum nutans). Botanical nomenclature followed the Great Plains Flora Association (1986). Tishomingo NWR encompasses a lake (Cumberland Pool), various ponds, and has streams and a river (Washita River) flowing through it (Figure 1).

Methods

Data on habitat requirements and distributional information for terrestrial vertebrates in Tishomingo NWR were obtained from a variety of sources, including published literature and refuge records (Table 2). Habitat associations were created using the Oklahoma Gap Analysis vegetative classification scheme (Figure 2). Animal distributions were predicted by: 1) determining whether or not the species occurred in Johnston or Marshall counties, Oklahoma, 2) determining if the species' habitat requirements could be met at Tishomingo NWR, and 3) identifying the potential distribution within the refuge. Those habitats were then mapped using polygons from a vegetative map created from aerial photography.

Using the Oklahoma Gap vegetative classification scheme, we identified 16 different habitat types on Tishomingo NWR (Table 1). We delineated those habitat types from 1991 aerial photography (1:16,330) of the refuge on transparent sheets and scanned them into the computer with an Eagle 3640 (ANA Tech, Littleton, CO) flatbed scanner. Scanned images were edited in Line Trace Plus, version 2.22 (Forest Service, Denver, CO). We brought the edited images into Arc/Info, version 7.0 (ESRI, Redlands, CA) where topology was created and the images were registered to real-world coordinates (Fig. 1). The final habitat coverage was used to plot potential distributions of each species within the refuge. Terrestrial habitats made up 56% and aquatic habitats made up 44% of the refuge. In addition to the terrestrial and aquatic habitats, we included a wetland habitat category to represent species that were associated with water. Other habitats represented different structural and vegetative species composition (Table 1). Oak/hickory forest and willow/cottonwood forest made up the majority (73%) of the terrestrial habitats (Table 1). The willow/cottonwood forest (35% of terrestrial habitats) was seasonally flooded. The barren habitat (4% of terrestrial habitats) represented exposed shorelines or rivers, ponds, and lakes.

Distributions of terrestrial vertebrate species in the refuge were predicted from the habitat map and used to model vertebrate communities. Because knowledge of the structure and function of ecological communities were incomplete (Schroeder and Haire 1993), we assumed that species occurrence was influenced strongly by habitat conditions (Morrison and others 1992), and the value of each habitat type was uniform among all areas with the same classification (Airola 1988), which applied to both within-habitat and between-habitat patch variation. We also assumed that: 1) absolute amounts of habitat present on Tishomingo NWR were adequate for each species, 2) special habitat requirements were represented by the habitat classification used, and 3) external factors (e.g., competition, disease, predation, and weather conditions) did not affect presence/absence of species in a habitat. The overall assumption was that species existed as components of larger systems (Noss and Harris 1986). Because of the limitations of the data used (Schroeder and Haire 1993) and the assumptions, this model will likely only predict species present at Tishomingo NWR. The resolution of the model was sensitive only for the given scale (e.g., no microhabitat data was included).

Small Mammals.—We snaptrapped small mammals (Hamilton and others 1987) in the following habitats: oak/hickory forest, willow/cottonwood forest, upland shrub, grassland, agriculture, and wetland. Trapping was the only practical method of determining presence of most small mammals (Williams and Braun 1983). Two transects of 250 m were placed in each habitat. We placed 6 trapping stations 50 m apart on each transect. Each station consisted of 2 rat traps and 3 museum-special traps. Traps were placed 1 m apart with 1 trap in the center and the other 4 forming a square around the center trap. We used peanut butter for bait (Brower and others 1990). All species of small mammals trapped were identified and recorded. We trapped at the end of May and the end of August to coincide with probable periods of peak abundance following reproductive activity (Schetter 1996). Bats were not included in the inventory due to difficulty in sampling.

Large Mammals.—We used scent stations to attract medium-sized and large mammals in the following habitats: oak/hickory forest, willow/cottonwood forest, grassland and shrub combined, and agriculture. We placed 5 scent stations in each habitat with ≥350-m separating each station (Hamilton and others 1987). Scent stations consisted of a 1-m diameter, sand-covered circle with vegetation removed. We used a fatty-acid scent disk (Pocatello Supply Depot, Pocatello, ID) as an attractant. We identified tracks to species whenever possible. Stations were active for 3 days in each habitat type in November 1996, January 1997, May 1997, and August 1997. Random observations of large mammals also were included in the inventory.

Avifauna.-Birds were surveyed with a modified point count in the following habitats: oak/hickory forest, willow/cottonwood forest, grassland and shrub combined, and oak woodland. We established a grid system in each habitat type such that 36 points/habitat were >100 m from an adjacent habitat and points were >60 m from each other (Schulz and others 1992). In each habitat, we randomly selected and sampled 6 points each season. Birds surveyed ≤100 m from the survey point were used in this study. We spent 10-min at each station with a 1-min waiting period before observations began (Avery and van Riper 1989, Schulz and others 1992). We identified species by sight, sound, or any combination of those cues (Emlen 1977). We performed surveys between sunrise and 4 h after sunrise to survey the maximum number of bird species (Shields 1977, Robbins 1981). Surveys were performed only when weather met the following criteria: no rain, no fog, and wind <20 kph (Robbins 1981). We surveyed birds in fall 1996 (October 5, 12, and 19), winter 1997 (January 18, 25, and February 8), spring 1997 (May 3, 4, 14, and 15), and summer 1997 (July 24, 25, and 26).

We performed surveys specifically for shorebirds using the Cumberland Pool on the refuge (Chapter IV). Those data and any random observations of birds were included in the inventory.

Herpetofauna.—We searched for herpetofauna on the same transects used for small mammals in the following habitats: oak/hickory forest, willow/cottonwood forest, upland shrub, grassland, agriculture, and wetland. Transects were 250 m long with the center of six circular plots (12.5 m radius) located 50 m apart. At least 2 people systematically searched each plot, and all species caught were identified and released. We performed surveys in consistent weather conditions (no rain or extreme temperatures), preferably after a rain (Corn and Bury 1990, Vogt and Hine 1982). Transects were searched in spring (May 13, 1996, and May 21, 1997), summer (August 10 and 11, 1996, and August 9 and 31, 1997), and fall (November 9, 1996, and November 15, 1997).

In addition to searching plots, we collected herpetofauna opportunistically (Bury and Raphael 1983) throughout the year. Opportunities included general searches, searches after thunderstorms and driving slow on refuge roads (both day and night) to locate snakes. Call indices (Vogt and Hine 1982) of frogs were performed at ponds, creeks, the Washita River, and the Cumberland Pool. We set up an 8.4-km standardized survey route for frogs and sampled it once a month from March to July, 1997. Those months include peak breeding seasons for all frogs at Tishomingo NWR (Black and Seivert 1989). Drift fences were used in summer 1997 to capture some species not yet found but presumed to occur on the refuge. Those data and other observations were included in the inventory.

Data from all field collections of each taxonomic group were compared to predicted presence of each vertebrate species. Omission, commission, and accuracy rates, given as percentages, were computed for each taxonomic group (Edwards and others 1996). We defined errors of omission as the number of species inventoried but not predicted at Tishomingo NWR. An error of commission was the number of species predicted but not inventoried. We defined accuracy as the percentage of species predicted and sampled at Tishomingo NWR (Edwards and others 1996). The number of commission errors, omission errors, matches, and percent accuracy were calculated for each taxonomic group in 3 habitat types: oak/hickory forest, willow/cottonwood forest, and grassland/shrub combined. Those habitats constituted 77% of the terrestrial habitat and were the only habitat types sampled for all different taxonomic groups. These calculations were used to evaluate the adequacy of the WHR model.

We used Chi-square analysis (Zar 1984) to determine if there was a difference between predicted and inventoried species. The experimental unit was the number of species within 1 taxonomic group of 1 habitat type. After testing for differences between predicted and inventoried species over all taxonomic groups, we tested each taxonomic group separately. We evaluated differences between taxonomic groups because of the different sampling methods for each group. All statistical tests were performed at $P < 0.05$.

Results

A total of 274 species was predicted to be present at Tishomingo NWR, including 21 amphibians, 161 birds, 34 mammals, and 58 reptiles. Using the WHR model created for Tishomingo NWR, distributions were mapped for each of those species (e.g., Figure 3, 4, 5). A total of 156 species was inventoried, including 8 amphibians, 107 birds, 17 mammals, and 24 reptiles (Table 2). Omission errors were lower than the commission errors for the taxonomic groups (Table 3). Omission errors were low, with a maximum 2.9% for mammals. The following species were inventoried and not predicted: marbled godwit (*Limosa fedoa*), house cat (*Felis domesticus*), Swainson's warbler (*Limnothlupis swainsonii*). Commission errors were high, with a minimum of 35.4% for birds. Accuracy was highest for birds (63.4%).

Overall accuracy of predicted vertebrates in the 4 taxonomic groups in each of the 3 habitat types was not high (<54%), with the highest accuracy for mammals in the willow/cottonwood forest (Table 4). Predicted amphibians were the least accurate in the grassland/shrub habitat. In general, commission errors were greater than omission errors by habitat types (Table 4), which paralleled the trend for taxonomic groups (Table 3).

There was a difference between predicted number of species across all taxonomic groups and habitat types and those that were inventoried at Tishomingo NWR ($\chi^2 = 41.57$, df = 11, $\underline{P} < .0001$). However, we found no difference between number of predicted species and number of inventoried species in the mammalian and amphibian groups ($\chi^2 = 4.26$, df = 2, $\underline{P} = 0.118$; $\underline{P} = 0.246$, respectively). We used Fisher's exact test (Zar 1984) for the amphibian taxonomic group because our data did not meet conditions of the Chi-square test (Cochran 1954). The predicted number of reptiles ($\chi^2 = 18.55$, df = 2, $\underline{P} < 0.001$) and birds ($\chi^2 = 13.51$, df = 2, $\underline{P} = 0.001$) differed between the number of inventoried species.

Discussion

Our analyses showed that omission errors were low (<3%) and commission error was high (>35%) for the WHR model that we developed for Tishomingo NWR. The high commission error resulted in a relatively low accuracy for all taxonomic groups (Table 3). Other studies (Dendon and others 1986, Avery and van Riper 1990, and Edwards and others 1996) also found that commission errors were higher than omission errors. We tried to incorporate all possible species into our WHR model, and therefore, high errors of commission were by design. The above mentioned studies all reported that their models over-predicted species, also by design. Avery and van Riper (1990) and Edwards and others (1996) argued that errors of commission were preferred to errors of omission because errors of omission meant that the model excluded species. Our WHR model had relatively low omission error (Table 3). However, this was not true when we observed errors for particular habitats types within Tishomingo NWR (Table 4).

Avery and van Riper (1990) reported considerable variability among habitat types in errors of omission when evaluating predictions for birds in their California WHR model. We also had variability in our errors of omission (Table 4). In general, the lowest errors of omission occurred in the grassland/shrub habitat, which was a combination of 4 small habitat categories on the refuge (Table 1); therefore, we might expect that there would be fewer omission errors because the combination of habitat categories included more possible species predictions. Low accuracy rates, high commission errors, and high omission errors indicate that our WHR model created for Tishomingo NWR does not have a good predictive performance for each habitat type (Table 4). Consequently, accuracy of predictions for each habitat type would not be reliable for management decisions on the refuge. Species may be left out by the prediction for specific habitats and potentially result in poor management decisions.

Accuracy for amphibians and reptiles was lower than for birds and mammals (Table 3), which is likely due to difficulties with inventorying herpetofauna (Heyer and others 1994). Edwards and others (1996) found a similar relationship while studying vertebrate distributions modeled from Gap Analysis in 8 national parks in Utah. Our Chi-square analysis indicated that species' frequencies of amphibians and mammals across habitat types did not differ between prediction and inventory methods but reptile and bird frequencies did differ. We expected our accuracy assessment and statistical differences to agree because they were measuring similar things.

Some studies (Block and others 1994, Edwards and others 1996) have described a trend between accuracy of a WHR model and the scale of the study. Edwards and others (1996) reported that with the exception of amphibians, error rates decreased as the size of the study area increased. They argued that as area increased, the probability of including more habitat types increased and, consequently, the species modeling approach of Gap Analysis was sufficient in large areas. Block and others (1994) suggested that statewide WHR models should not be used to predict species presence in specific locations. They also suggested that accuracy of models will improve if they are developed for individual management areas. We created a WHR model for a small management area. Whether habitat associations are created for large areas, like Gap Analysis, or for small areas like the site-specific WHR model for Tishomingo NWR, similar sources of information are used to determine habitat requirements and range distributions for terrestrial vertebrates. Our results indicate that the difference between WHR model scales is the ability to map habitat types. We believe that refined landscape-level WHR models have real potential for small management areas. If we had included ancillary data like soil type, elevation, hydrography, habitat features, etc., our model may have been more refined and had less error.

The primary use of the WHR model created for Tishomingo NWR is to provide lists of species that might be found in a particular habitat types. Given our high commission error rates (Table 4), habitat-specific predictions with our WHR models are presently unreliable. However, we did have very low omission rates for all terrestrial vertebrates predicted to be at Tishomingo NWR (Table 3). There is still utility in the habitat-specific predictions because potential distributions of terrestrial vertebrates at the refuge can be used as another source of input in management decisions and habitat restoration.

Our model can be improved. Species lists compiled from field surveys will likely lead to lower errors of commission that would be found correct with long-term inventories (Csuti and Crist 1998). Therefore, long-term inventories should improve the accuracy of the WHR over time. Also, the model can be improved as scientific literature grows for each species, and factors that affect their presence are better understood. We also believe that a site-specific classification system would improve model accuracy. This habitat classification could include additional habitat features (e.g., microhabitats) that fulfill requirements of individual species. The classification should be built after habitat requirements for each species have been ascertained. This would allow prediction of species' presence at a scale required for a particular species. Hopefully, the result would be a predictive model that could be used to predict generalist and specialist species (Edwards and others 1996).

ACKNOWLEDGEMENTS

We thank the Trust for Public Land, Tishomingo National Wildlife Refuge, and the Oklahoma Cooperative Fish and Wildlife Research Unit (Oklahoma Department of Wildlife Conservation, Oklahoma State University, U.S. Geological Survey's Biological Resource Division, and Wildlife Management Institute, cooperating) for financial and logistcial support. Special thanks to D. Stanbrough, J. Beall, and M. Gregory for their individual efforts. We acknowledge S. Chappell, A. Craft, J. James, S. Larrabee, J. Sinclair, D. Underwood, and J. Webster for their assistance in the field.

Literature Cited

Airola, D. A. 1988. A guide to the California wildlife habitat relationships system. California Department Fish and Game, Sacramento. 74pp.

American Ornithologists' Union. 1983. Check-list of the American Ornithologists' Union. Allen Press Inc., Lawrence, Kansas.

Avery, M. L. and C. van Riper III. 1989. Seasonal changes in bird communities of the chaparral and blue-oak woodlands in central California. Condor 91:288-295.

_____, and _____. 1990. Evaluation of wildlife-habitat relationships database for predicting bird community composition in central California chaparral and blue oak woodlands. California Fish and Game 76:103-117.

Bailey, V. 1971. Mammals of the southwestern United States. Dover Publications, Inc., New York, New York.

Bishop S. C. 1947. Handbook of salamanders. Comstock Publisher Company, Inc., Ithaca, New York.

Black, J. H., and G. Sievert. 1989. A field guide to amphibians of Oklahoma. Oklahoma Department of Wildlife Conservation, Oklahoma City.

Block, W. M., M. L. Morrison, J. Verner, and P. N. Manley. 1994. Assessing wildlife-habitat-relationships models: a case study with California oak woodlands. Wildlife Society Bulletin 22:549-561.

Brower, J. E., J. H. Zar, and C. N. von Ende. 1990. Field and laboratory methods for general ecology. Third ed. Wm. C. Brown Publishers, Dubuque. 237pp.

Brown, S., H. Schreier, W. A. Thompson, and I. Vertinsky. 1994. Linking multiple accounts with GIS as decision support system to resolve forestry/wildlife conflicts. Journal of Environmental Management 42:349-364.

Bury, R. B., and M. G. Raphael. 1983. Inventory methods for amphibians and reptiles. Pages 416-419 *in* N. J. Scott, ed. Proceeding of the Southern Evaluation Workshop. Southern Forest Experiment Station, Louisiana, New Orleans.

Caire, W., J. D. Tyler, B. P. Glass, and M. A. Mares. 1989. Mammals of Oklahoma. University of Oklahoma Press, Norman, Oklahoma City.

Carr, A. 1952. Handbook of turtles. Comstock Publishing Associates, Ithaca, New York.

Clark, J. D., J. E. Dunn, and K. G. Smith. 1993. A multivariate model of female black bear habitat use for a geographic information system. Journal of Wildlife Management 57:519-526.

Chapman, J. A. and G. A. Feldhammer. 1982. Wild mammals of North America. The Johns Hopkins University Press, Baltimore, Maryland.

Choate, J. R. 1994. Handbook of mammals of the south-central states. Louisiana State University Press, Baton Rouge, Louisiana.

Chow, L., J. V. Wagtendonk, S. Thompson, and K. Mccurdy. 1994. Using wildlife habitat relationship models for land use planning for Yosemite Valley. Transactions of the Western Section of the Wildlife Society 30:49-55.

Cochran, W. G. 1954. Some methods for strengthening the common chi-square tests. Biometrics 10:417-451.

Collins, J. T. and S. L. Collins. 1993. Amphibians and reptiles in Kansas. University Press of Kansas, Lawrence, Kansas.

Congalton, R. G., and K. Green. 1992. The ABCs of GIS. Journal of Forestry. 90:13-20.

Corn, P. S., and R. B. Bury. 1990. Wildlife-habitat relationships: sampling procedures for Pacific Northwest Vertebrates. General Technical Report PNW-GTR-256. Portland, OR. 34pp.

Csuti, B., and P. Crist. 1998. Methods for assessing accuracy of animal distribution maps (version 2). *In* J. M. Scott and M. D. Jennings, eds. A handbook for GAP Analysis, Idaho Coop. Fish Wildl. Res. Unit, Univ. Idaho, Moscow.

Davis, W. B. and D. J. Schmidly. 1994. The mammals of Texas. Texas Parks and Wildlife, Austin, Texas.

Dendon, M. F., S. A. Laymon, and R. H. Barrett. 1986. Evaluating models of wildlife-habitat relationships of birds in black oak and mixed-conifer habitats. Pages 115-119 *in* J. Verner, M. L. Morrison, and C. J. Ralph, ed. Wildlife 2000: Modeling Habitat Relationships of Terrestrial Vertebrates. University of Wisconsin Press, Madison, Wisconsin.

Duck, L. G., and J. B. Fletcher. 1943. A game type map of Oklahoma. Oklahoma Game and Fish Dept., Oklahoma City.

Edwards, T. C., E. T. Deshler, D. Foster, and G. G. Moisen. 1996. Adequacy of wildlife habitat relation models for estimating spatial distributions of terrestrial vertebrates. Conservation Biology 10:263-270.

Emlen, J. T. 1977. Estimating breeding season bird densities from transect counts. Auk 94:455-468.

Garrett, J. M. and D. G. Barker. 1987. A field guide to reptiles and amphibians of Texas. Texas Monthly Press, Austin, Texas.

Great Plains Flora Association. 1986. Flora of the Great Plains. University Press of Kansas, Lawrence, Kansas. 1392 pp.

Hamilton, R. B., S. W. Ellsworth, and J. C. Smith. 1987. Mammalian use of habitat in the loblolly-shortleaf pine type of Louisiana. Pages 81-91 *in* H. A. Pearson, F. E. Smeins, and R. E. Thill, eds. Proceedings of the Southern Evaluation Workshop. Southern Forest Experiment Station, New Orleans, Louisiana.

Harris, L. K., R. H. Gimblett, and W. W. Shaw. 1995. Multiple use management: using a GIS model to understand conflicts between recreationists and sensitive wildlife. Society and Natural Resources 8:559-572.

Heyer, W. R., M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. Foster, editors. 1994. Measuring and monitoring biological diversity. Standard methods for amphibians. Smithsonian Institution Press, Washington, D.C.

Johnsgard, P. A. 1979. Birds of the Great Plains: Breeding species and their distribution. University of Nebraska, Lincoln, Nebraska.

Jones, Jr., J. K., D. M. Armstrong, R. S. Hoffman, and C. Jones. 1983. Mammals of the northern Great Plains. University of Nebraska Press, Lincoln, Nebraska.

Jones, Jr., J. K., D. M. Armstrong, and J. R. Choate. 1985. Guide to mammals of the plains states. University of Nebraska Press, Lincoln, Nebraska.

Morrison, M. L., B. G. Marcot, and R. W Manna. 1992. Wildlife-Habitat Relationships: Concepts and Applications. Univ. of Wisconsin Press, Madison. 343pp.

Noss, R. F., and L. D. Harris. 1986. Nodes, networks, and MUMs: preserving diversity at all scales. Environmental Management 10:299-309.

Pereira, J. M. C. and R. M. Itami. 1991. GIS-based habitat modelling using logistic multiple regression: a study of the Mt. Graham red squirrel. Photogrammetric Engineering and Remote Sensing 57:1475-1486.

Robbins, C. S. 1981. Effect of time of day on bird activity. Pages 275-286 *in* R. J. Raitt and J. P.

Thompson, ed. Estimating numbers of terrestrial birds. Cooper Ornithological Society, Lawrence, Kansas.

Robbins, M. B. 1992. Birds of Missouri: their distribution and abundance. University of Missouri Press, Columbia, Missouri.

Schamberger, M. L., and L. J. O'Neil. 1984. Concepts and constraints of habitat-model testing. Pages 5-10 in J. Verner, M. L. Morrison, and C. J. Ralph, eds. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Univ. Wisconsin Press, Madison.

Schetter, T. 1996. Evaluation of the nitrogen limitation hypothesis in populations of cotton rats (Sigmodon hispidus). M.S. Thesis, Oklahoma State University, Stillwater, OK.

Schroeder, R. L., and S. L. Haire. 1993. Guidelines for the development of community-level habitat evaluation models. U.S. Fish and Wildlife Service Biological Report 8. 9pp.

Schulz, C. A., D. M. Leslie, Jr., and R. L. Lochmiller. 1992. Autumn and winter bird populations in herbicide-treated cross timbers in Oklahoma. American Midland Naturalist 127:215-223.

Scott, J. M., F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'erchia, T. C. Edwards, Jr., J. Ulliman, and R. G. Wright. GAP analysis: a geographic approach to protection of biological diversity. Wildlife Monographs 123:1-41.

Sealander, J. A. 1979. A guide to Arkansas mammals. River Road Press, Conway, Arkansas.

Sievert, G. and L. Sievert. 1983. A field guide to reptiles of Oklahoma. Oklahoma Department of Wildlife Conservation, Oklahoma, Oklahoma City.

Shaw, D. M. and S. F. Atkinson. 1990. An introduction to the use of geographic information systems for ornithological research. Condor 92:564-570.

Shields, W. M. 1977. The effect of time of day on avian census results. Auk 94:380-383.

Smith, H. M. 1946. Handbook of lizards. Comstock Publishing Co., Ithaca, New York.

Thompson, M. C. and C. Ely. 1989. Birds in Kansas. University Press of Kansas, Lawrence, Kansas.

Timothy, K. G. and D. F. Stauffer. 1991. Reliability of selected avifauna information in a computerized information system. Wildlife Society Bulletin 19:80-88.

Vogt, R. C., and R. L. Hine. 1982. Evaluation of techniques for assessment of amphibian and reptile populations in Wisconsin. Pages 201-217 *in* N. J. Scott, ed. Herpetological Communities: A symposium of the Society for the Study of Amphibians and Reptiles and the Herpetologists' League.

Williams, D. F., and S. E. Braun. 1983. Comparison of pitfall and conventional traps for sampling small mammal populations. Journal Wildlife Management 47:841-845.

Wright, A. H. and A. A. Wright. 1949. Handbook of frogs and toads of the United States and Canada. Cornell University Press, Ithaca, New York.

Wright, A. H. and A. A. Wright. 1957. Handbook of snakes of the United States and Canada. Cornell University Press, Ithaca, New York.

Wood, D. S. and G. D. Schnell. 1984. Distributions of Oklahoma Birds. University of Oklahoma Press, Norman, oklahoma.

Zar, J. H. 1984. Biostatistical analysis. 2nd ed. Prentice-Hall, Englewood Cliffs, NJ. 718 pp.

Table 1. Oklahoma Gap codes, height, canopy cover, and area estimates for habitat types delineated on 1991 aerial photographs for Tishomingo National Wildlife Refuge, Oklahoma.

Habitat Type	Gap Code[1]	Height of Vegetation (m)	Canopy Cover (%)	Area (ha)	Area (%)
Lake	DWL	NA	NA	2,219.1	33.27
Oak/Hickory Forest	FB3a3	>5	61-100	1,454.4	21.81
Willow/Cottonwood Forest	FB3c1	>5	61-100	1,307.4	19.60
Pond	DWPO	NA	NA	591.9	8.87
Agriculture	DA	NA	NA	345.5	5.18
Oak Woodland	WB3a1	>5	26-60	280.3	4.20
Barren	BB	<1	NA	129.5	1.94
River	DWR	NA	NA	115.2	1.73
Lowland Shrub	SB3c1	<5	>26	74.5	1.12

Table 1. Continued.

Habitat Type	Gap Code[1]	Height of Vegetation (m)	Canopy Cover (%)	Area (ha)	Area (%)
Upland Shrub	SB3c4	<5	>26	46.1	0.69
Grassland (with shrub)	HB2c1	<1	<25	38.5	0.58
Urban, vegetated	DUV	NA	NA	32.4	0.49
Grassland (with trees)	HB1c1	<1	<25	31.6	0.47
Marsh	HA4c3	>1	<25	1.5	0.02
Willow Woodland	WB3a2	>5	26-60	0.9	0.01
Buttonbush shrub	SB3c6	<5	>26	0.5	0.00
Wetland[2]	-	-	-	-	-

[1]Vegetative code used by Oklahoma GAP analysis (W. L. Fisher, pers. comm.).

Table 1. Continued.

[2]Wetland habitat includes all shoreline on permanent bodies of water and therefore has no area.

Table 2. Common name, scientific name, and inventoried status of terrestrial vertebrates predicted to be present at Tishomingo National Wildlife Refuge, Oklahoma.

Common name	Scientific Name	Inventoried
Amphibians (21 total)		
Barred Tiger Salamander	Ambystoma tigrinum	
Blanchard's Cricket Frog	Acris crepitans	X
Bullfrog	Rana catesbeiana	X
Central Newt	Notophthalmus viridescens	
Crawfish Frog	Rana areolata	
Dwarf American Toad	Bufo americanus	X
Eastern Narrowmouth Toad	Gastrophryne carolinensis	X
Gray Treefrog	Hyla versicolor	X
Great Plains Narrowmouth Toad	Gastrophryne olivacea	

Table 2. Continued.

Common name	Scientific Name	Inventoried
Great Plains Toad	Bufo cognatus	
Green Frog	Rana clamitans	
Green Treefrog	Hyla cinerea	
Hurter's Spadefoot	Scaphiopus holbrooki	X
Plains Leopard Frog	Rana blairi	
Plains Spadefoot	Scaphiopus bombifrons	
Smallmouth Salamander	Ambystoma texanum	
Southern Leopard Frog	Rana utricularia	X
Spotted Chorus Frog	Pseudacris clarkii	
Strecker's Chorus Frog	Pseudacris streckerii	
Western Chorus Frog	Pseudacris triseriata	
Woodhouse's Toad	Bufo woodhousii	X

Table 2. Continued.

Common name	Scientific Name	Inventoried
Birds (161 total)		
American Avocet	Recurvirostra americana	X
American Coot	Fulica americana	X
American Crow	Corvus brachyrhynchos	X
American Goldfinch	Carduelis tristis	X
American Kestrel	Falco sparverius	X
American Robin	Turdus migratorius	X
American White Pelican	Pelecanus erythrorhynchos	X
American Wigeon	Anas americana	
Baird's Sandpiper	Calidrus bairdii	
Bald Eagle	Haliaeetus leucocephalus	X

Table 2. Continued.

Common name	Scientific Name	Inventoried
Bank Swallow	Ripria riparia	
Barred Owl	Strix varia	X
Barn Swallow	Hirundo rustica	X
Bell's Vireo	Vireo bellii	
Belted Kingfisher	Ceryle alcyon	X
Bewick's Wren	Thryomanes bewickii	X
Black Tern	Chlidonias niger	
Black Vulture	Coragyps atratus	X
Blackcrowned Night-Heron	Nycticorax nycticorax	
Blue Grosbeak	Guiraca caerulea	X
Blue Jay	Cyanocitta cristata	X
Blue-Gray Gnatcatcher	Polioptila caerulea	X

Table 2. Continued.

Common name	Scientific Name	Inventoried
Blue-Winged Teal	<u>Anas discors</u>	
Bobolink	<u>Dolichonyx oryzivorus</u>	
Brown Creeper	<u>Certhia americana</u>	X
Brown Thrasher	<u>Toxostoma rufum</u>	X
Brown-Headed Cowbird	<u>Molothrus ater</u>	X
Bufflehead	<u>Bucephala albeola</u>	
Canada Goose	<u>Branta canadensis</u>	X
Canvasback	<u>Aythya valisineria</u>	
Carolina Chickadee	<u>Parus carolinensis</u>	X
Carolina Wren	<u>Thryothorus ludovicianus</u>	X
Cattle Egret	<u>Bubulcus ibis</u>	X
Cerulean Warbler	<u>Dendroica cerulea</u>	

Table 2. Continued.

Common name	Scientific Name	Inventoried
Chimney Swift	_Chaetura pelagica_	X
Chuck-Will's-Widow	_Caprimulgus carolinensis_	X
Cliff Swallow	_Hirundo pyrrhonota_	
Common Grackle	_Quiscalus quiscula_	X
Common Merganser	_Mergus merganser_	
Common Nighthawk	_Chordeiles minor_	
Common Snipe	_Gallinago gallinago_	
Common Tern	_Sterna hirundo_	
Common Yellowthroat	_Geothlypis trichas_	
Cooper's Hawk	_Accipiter cooprii_	X
Dark-Eyed Junco	_Junco hyemalis_	X
Dickcissel	_Spiza americana_	X

Table 2. Continued.

Common name	Scientific Name	Inventoried
Double-Crested Cormorant	Phalacrocorax auritus	X
Downy Woodpecker	Picoides pubescens	X
Eastern Bluebird	Sialia sialis	X
Eastern Kingbird	Tyrannus tyrannus	X
Eastern Meadowlark	Sturnella magna	
Eastern Phoebe	Sayornis phoebe	X
Eastern Screech-Owl	Otus asio	X
European Starling	Sturnus vulgaris	X
Field Sparrow	Spizella pusilla	X
Fish Crow	Corvus ossifragus	X
Forster's Tern	Sterna forsteria	
Fox Sparrow	Passerella iliaca	X

Table 2. Continued.

Common name	Scientific Name	Inventoried
Franklin's Gull	*Larus pipixcan*	X
Gadwall	*Anas strepera*	
Gray Catbird	*Dumetella carolinensis*	X
Great Blue Heron	*Ardea herodias*	X
Great Crested Flycatcher	*Myiarchus crinitus*	X
Great Egret	*Casmerodius albus*	X
Great Horned Owl	*Bubo virginianus*	X
Great-Tailed Grackle	*Quiscalus mexicanus*	
Greater Roadrunner	*Geococcyx californianus*	X
Greater White-Fronted Goose	*Anser albifrons*	X
Greater Yellowlegs	*Tringa melanleuca*	X
Green-Backed Heron	*Butorides striatus*	

Table 2. Continued.

Common name	Scientific Name	Inventoried
Green-Winged Teal	*Anas crecca*	
Hairy Woodpecker	*Picoides villosus*	
Harris' Sparrow	*Zonotrichia querula*	
Herring Gull	*Larus argentatus*	X
Hooded Merganser	*Lophodytes cucullatus*	
Horned Lark	*Eremophila alpestris*	
House Sparrow	*Passer domesticus*	X
Indigo Bunting	*Passerina cyanea*	X
Killdeer	*Charadrius vociferus*	X
Lark Sparrow	*Chondestes grammacus*	
Least Flycatcher	*Empidonax minimus*	
Least Sandpiper	*Calidris minutilla*	X

Table 2. Continued.

Common name	Scientific Name	Inventoried
Lesser Scaup	*Aythya affinis*	X
Lesser Yellowlegs	*Tringa flavipes*	X
Lincoln's Sparrow	*Melospiza lincolnii*	
Little Blue Heron	*Egretta caerulea*	
Loggerhead Shrike	*Lanius ludovicianus*	X
Long-Billed Dowitcher	*Limnodromus scolopaceus*	
Mallard	*Anas platyrhynchos*	X
Mississippi Kite	*Ictinia mississippiensis*	X
Mourning Dove	*Zenaida macroura*	X
Nashville Warbler	*Vermivora ruficapilla*	
Northern Bobwhite	*Colinus virginianus*	X
Northern Cardinal	*Cardinalis cardinalis*	X

Table 2. Continued.

Common name	Scientific Name	Inventoried
Northern Flicker	Colaptes auratus	X
Northern Harrier	Circus cyaneus	X
Northern Mockingbird	Mimus polyglottos	X
Northern Pintail	Anas acuta	
Northern Rough-Winged Swallow	Stelgidopteryx serripennis	
Northern Shoveler	Anas clypeata	X
Orange-Crowned Warbler	Vermivora celata	X
Orchard Oriole	Icterus spurius	
Painted Bunting	Passerina ciris	X
Pectoral Sandpiper	Calidris melanotos	
Pied-Billed Grebe	Podilymbus podiceps	X
Pileated Woodpecker	Dryocopus pileatus	X

Table 2. Continued.

Common name	Scientific Name	Inventoried
Prothonotary Warbler	*Protonotaria citrea*	X
Purple Finch	*Carpodacus purpureus*	
Purple Martin	*Progne subis*	X
Red-Bellied Woodpecker	*Melanerpes carolinus*	X
Red-Eyed Vireo	*Vireo olivaceus*	
Red-Headed Woodpecker	*Melanerpes erthrocephalus*	X
Red-Shouldered Hawk	*Buteo lineatus*	X
Red-Tailed Hawk	*Buteo jamaicensis*	X
Red-Winged Blackbird	*Agelaius phoeniceus*	X
Redhead	*Aythya americana*	
Ring-Billed Gull	*Larus delawarrensis*	X
Ring-Necked Duck	*Aythya collaris*	

Table 2. Continued.

Common name	Scientific Name	Inventoried
Rock Dove	Columba livia	
Rose-Breasted Grosbeak	Pheucticus ludovicianus	X
Ross' Goose	Chen rossii	X
Rough-Legged Hawk	Buteo lagopus	
Ruby-Crowned Kinglet	Regulus calendula	X
Ruby-Throated Hummingbird	Archilochus colubris	X
Rufous-Sided Towhee	Pipilo erythrophthalmus	
Rusty Blackbird	Euphagus carolinus	
Savannah Sparrow	Passerculus sandwichensis	
Scissor-Tailed Flycatcher	Tyrannus forficatus	X
Semipalmated Sandpiper	Calidris pusilla	
Snow Goose	Chen caerulescens	X

Table 2. Continued.

Common name	Scientific Name	Inventoried
Snowy Egret	Egretta thula	X
Solitary Sandpiper	Tringa solitaria	X
Song Sparrow	Melospiza melodia	X
Spotted Sandpiper	Actitis macularia	X
Summer Tanager	Piranga rubra	
Swaison's Thrush	Catharus ustalatus	
Swamp Sparrow	Melospiza georgiana	
Tennessee Warbler	Vermivora peregrina	
Tufted Titmouse	Parus bicolor	X
Turkey Vulture	Cathartes aura	X
Upland Sandpiper	Bartramia longicauda	X
Vesper Sparrow	Pooecetes gramineus	

Table 2. Continued.

Common name	Scientific Name	Inventoried
Virginia Rail	*Rallus limicola*	
Warbling Vireo	*Vireo gilvus*	
Water Pipit	*Anthus spinoletta*	
Western Kingbird	*Tyrannus verticalis*	
Western Sandpiper	*Calidrus minutilla*	X
White-Breated Nuthatch	*Sitta carolinensis*	X
White-Crowned Sparrow	*Zonotrichia leucophrys*	
White-Eyed Vireo	*Vireo griseus*	
White-Rumped Sandpiper	*Calidrus fuscicollis*	
White-Throated Sparrow	*Zonotrichia albicollis*	X
Wild Turkey	*Meleagris gallopavo*	X
Willet	*Catoptrophorus semipalmatus*	X

Table 2. Continued.

Common name	Scientific Name	Inventoried
Willow Flycatcher	*Empidonax traillii*	X
Wilson's Phalarope	*Phalaropus tricolor*	X
Winter Wren	*Troglodytes troglodytes*	X
Wood Duck	*Aix sponsa*	X
Yellow Warbler	*Dendroica petechia*	X
Yellow-Billed Cuckoo	*Coccyzus americanus*	X
Yellow-Breasted Chat	*Icteria virens*	
Yellow-Rumped Warbler	*Dendroica coronata*	X
Yellow-Throated Warbler	*Dendroica dominica*	X

Table 2. Continued.

Common name	Scientific Name	Inventoried
Mammals (34 total)		
Armadillo	Dasypus novemcinctus	X
Badger	Taxidea taxus	
Beaver	Castor canadensis	X
Black Rat	Rattus rattus	
Black-Tailed Jack Rabbit	Lepus californicus	
Bobcat	Lynx rufus	X
Coyote	Canus latrans	X
Deer Mouse	Peromyscus maniculatus	X
Eastern Mole	Scalopus aquaticus	
Eastern Woodrat	Neotoma floridana	X

Table 2. Continued.

Common name	Scientific Name	Inventoried
Eastern Cottontail	Sylvilagus floridanus	X
Elliot's Short-Tailed Shrew	Blarina hylophaga	X
Feral Hog	Sus scrofa	X
Fox Squirrel	Sciurus niger	X
Fulvous Harvest Mouse	Reithrodontomys fulvescens	X
Gray Fox	Urocyon cinereoargenteus	
Hispid Cotton Rat	Sigmodon hispidus	X
Hispid Pocket Mouse	Perognathus hispidus	
House Mouse	Mus musculus	
Least Shrew	Cryptotis parva	
Marsh Rice Rat	Oryzomys palustris	
Norway Rat	Rattus norvegicus	

Table 2. Continued.

Common name	Scientific Name	Inventoried
Opossum	Didelphis virginiana	X
Plain Pocket Gopher	Geomys bursarius	
Plains Harvest Mouse	Reithrodontomys montanus	
Raccoon	Procyon lotor	X
Red Fox	Vulpes vulpes	
Ringtail	Bassariscus astutus	
Striped Skunk	Mephitis mephitis	X
Texas Mouse	Peromyscus attwateri	
Thirteen-Lined Ground Squirrel	Spermophilus tridecemlineatus	
White-Footed Mouse	Peromyscus leucopus	X
White-Tailed Deer	Odocoileus virginianus	X
Woodland Vole	Microtus pinetorum	

Table 2. Continued.

Common name	Scientific Name	Inventoried
Reptiles (58 total)		
Alligator Snapping Turtle	Macroclemys temminckii	
Black Rat Snake	Elaphe obsoleta	X
Blind Snake	Leptotyphlops dulcis	
Broadhead Skink	Eumeces laticeps	X
Brown Snake	Storeria dekayi	X
Bullsnake	Pituophis melanoleucus	
Coachwhip	Masticophis flagellum	
Common Garter Snake	Thamnophis sirtalis	X
Common Musk Turtle	Sternotherus odoratus	
Common Snapping Turtle	Chelydra serpentina	X

Table 2. Continued.

Common name	Scientific Name	Inventoried
Copperhead	Agkistrodon contortrix	X
Diamonback Water Snake	Nerodia rhombifer	X
Eastern Collard Lizard	Crotaphytus collaris	
Eastern Hognose Snake	Heterodon platirhinos	X
Fence Lizard	Sceloporus undulatus	X
Five-Lined Skink	Eumeces fasciatus	X
Flathead Snake	Tantilla gracilis	X
Graham's Crayfish Snake	Regina grahamii	
Great Plains Rat Snake	Elaphe guttata	
Great Plains Skink	Eumeces obsoletus	
Ground Skink	Scincella lateralis	X
Ground Snake	Sonora semiannulata	

Table 2. Continued.

Common name	Scientific Name	Inventoried
Lined Snake	*Tropidoclonion lineatum*	
Midland Smooth Softshell	*Apalone mutica*	
Milk Snake	*Lampropeltis triangulum*	
Mississippi Mud Turtle	*Kinosternon subrubrum*	
Missouri River Cooter	*Pseudemys concinna*	
Northern Redbelly Snake	*Storeria occipitomaculata*	X
Northern Water Snake	*Nerodia sipedon*	X
Ornate Box Turtle	*Terrapene ornata*	X
Ouachita Map Turtle	*Graptemys pseudogeographica*	X
Plainbelly Water Snake	*Nerodia erythogaster*	
Prairie Kingsnake	*Lampropeltis calligaster*	
Racer	*Coluber constrictor*	

Table 2. Continued.

Common name	Scientific Name	Inventoried
Racerunner	Cnemidophorus sexlineatus	X
Razorback Musk Turtle	Sternotherus carinatus	
Red-Eared Turtle	Trachemys scripta	X
Ringneck Snake	Diadophis punctatus	
Rough Earth Snake	Virginia striatula	
Rough Green Snake	Opheodrys aestivus	X
Southern Coal Skink	Eumeces anthracinus	
Southern Prairie Skink	Eumeces septentrionalis	
Speckled Kingsnake	Lampropeltis getula	
Spiny Softshell	Apalone spinifera	X
Texas Horned Lizard	Phrynosoma cornutum	
Texas Spotted Whiptail	Cnemidophorus gularis	

Table 2. Continued.

Common name	Scientific Name	Inventoried
Three-Toed Box Turtle	Terrapene carolina	X
Timber Rattlesnake	Crotalus horridus	X
Western Chicken Turtle	Deirochelys reticularia	
Western Cottonmouth	Agkistrodon piscivorous	X
Western Diamonback Rattlesnake	Crotalus atrox	
Western Earth Snake	Virginia valeriae	
Western Hognose Snake	Heterodon nasicus	
Western Massasauga	Sistrurus catenatus	
Western Mud Snake	Farancia abacura	
Western Pygmy Rattlesnake	Sistrurus miliarius	
Western Ribbon Snake	Thamnophis proximus	X
Western Slender Glass Lizard	Ophisaurus attenuatus	

Table 3. Omission error, commission error, and accuracy of Wildlife-Habitat-Relationship Model by taxonomic group for Tishomingo National Wildlife Refuge, Oklahoma.

Taxonomic Group	Omission (%)	Commission (%)	Accuracy (%)
Amphibians	0.0	65.0	35.0
Avifauna	1.2	35.9	64.1
Mammals	2.9	50.0	50.0
Reptiles	0.0	58.6	41.4

Table 4. Number of commission errors (Nc), omission errors (No), matches (Na), and accuracy[1] for 4 taxonomic groups in 3 habitat types at Tishomingo National Wildlife Refuge, Oklahoma.

	Oak/Hickory Forest				Willow/Cottonwood Forest				Grassland/Shrub Combined			
Taxon	Nc	No	Na	Accuracy	Nc	No	Na	Accuracy	Nc	No	Na	Accuracy
Amphibians	1	2	1	25.0	4	2	1	14.3	6	2	0	0.0
Birds	13	22	7	16.6	14	16	15	33.3	54	18	30	29.4
Mammals	6	3	7	43.8	5	2	8	53.3	13	5	6	25.0
Reptiles	7	7	6	30.0	8	1	1	10.0	22	2	3	11.1

[1]Percent accuracy = [(Na/(Nc+No+Na)] X 100.

Figure 1. Habitat types of Tishomingo National Wildlife Refuge, Oklahoma (see Table 1 for description of habitat acronyms).

Figure 2. Flowchart for a wildlife-habitat relationship model created for Tishomingo National Wildlife Refuge, Oklahoma.

Figure 3. Distribution of the timber rattlesnake (Crotalus horridus) predicted by a wildlife-habitat relation model for Tishomingo National Wildlife Refuge, Oklahoma.

Figure 4. Distribution of the bobcat (Lynx rufus) predicted by a wildlife-habitat relation model for Tishomingo National Wildlife Refuge, Oklahoma.

Figure 5. Distribution of the scissor-tailed flycatcher (Tyrannus forficatus) predicted by a wildlife-habitat relation model for Tishomingo National Wildlife Refuge, Oklahoma.

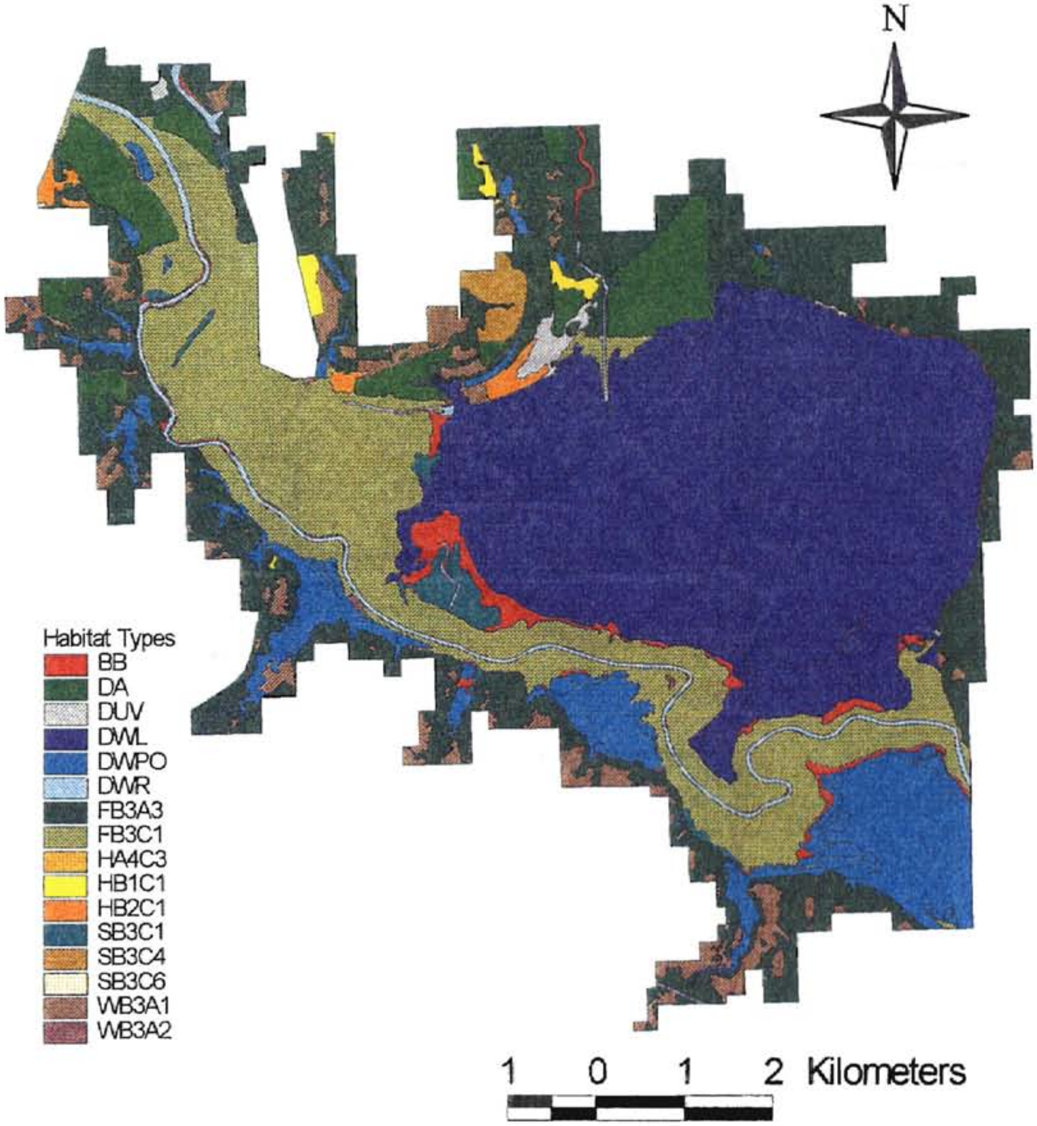

N
Habitat Types
BB
DA
DUV
DWL
DWPO
DWR
FB3A3
FB3C1
HA4C3
HB1C1
HB2C1
SB3C1
SB3C4
SB3C6
WB3A1
WB3A2
1 0 1 2 Kilometers

Figure 1

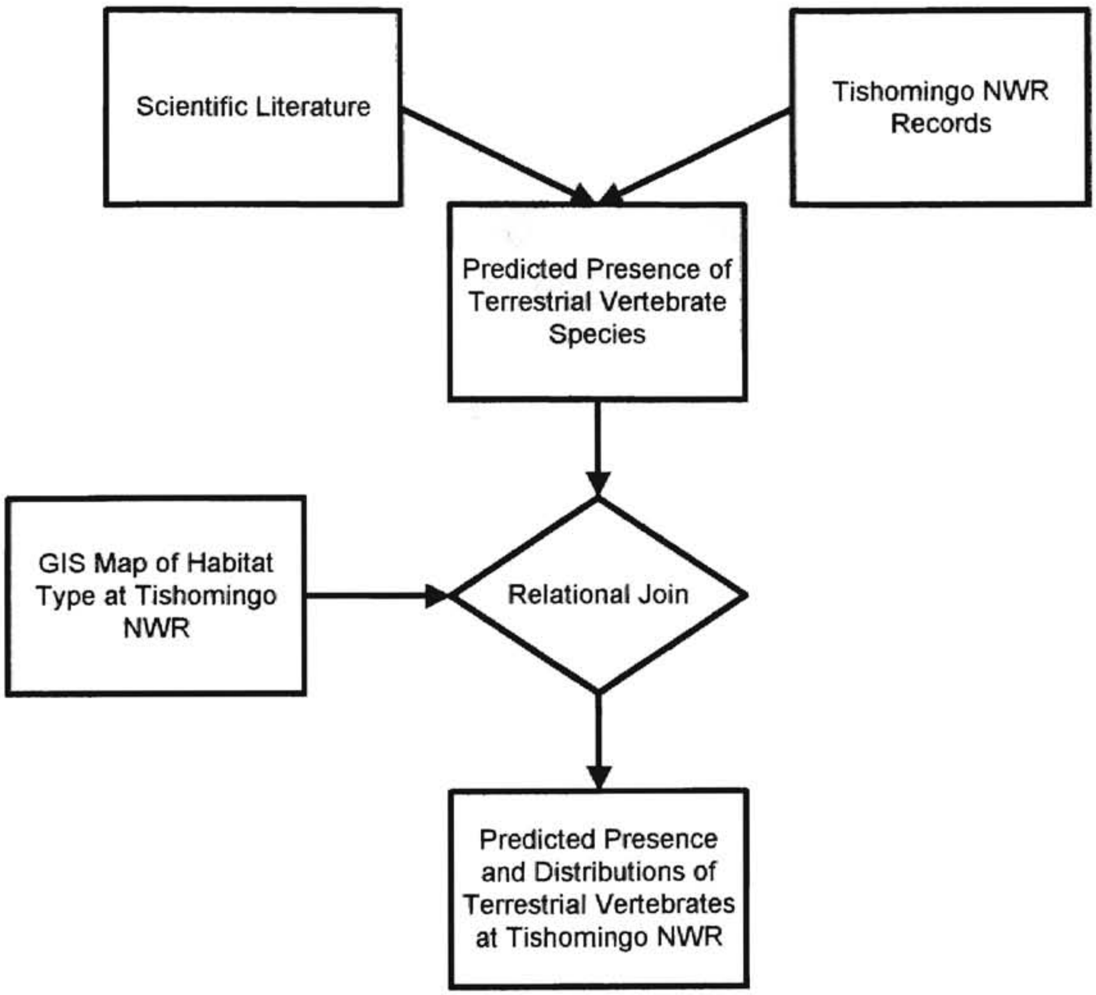

Scientific Literature
Tishomingo NWR Records
Predicted Presence of Terrestrial Vertebrate Species
GIS Map of Habitat Type at Tishomingo NWR
Relational Join
Predicted Presence and Distributions of Terrestrial Vertebrates at Tishomingo NWR

Figure 2

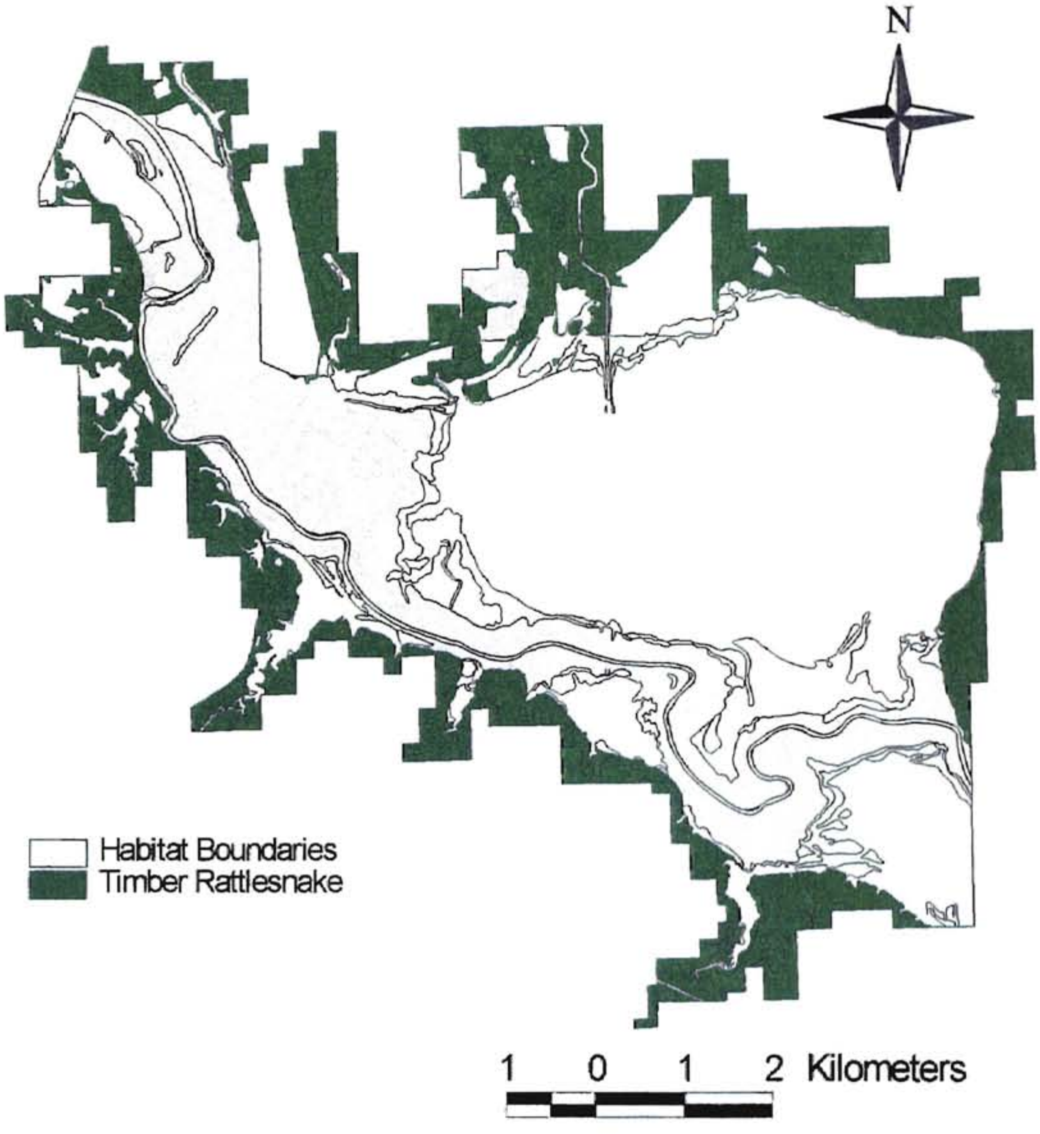


Figure 3

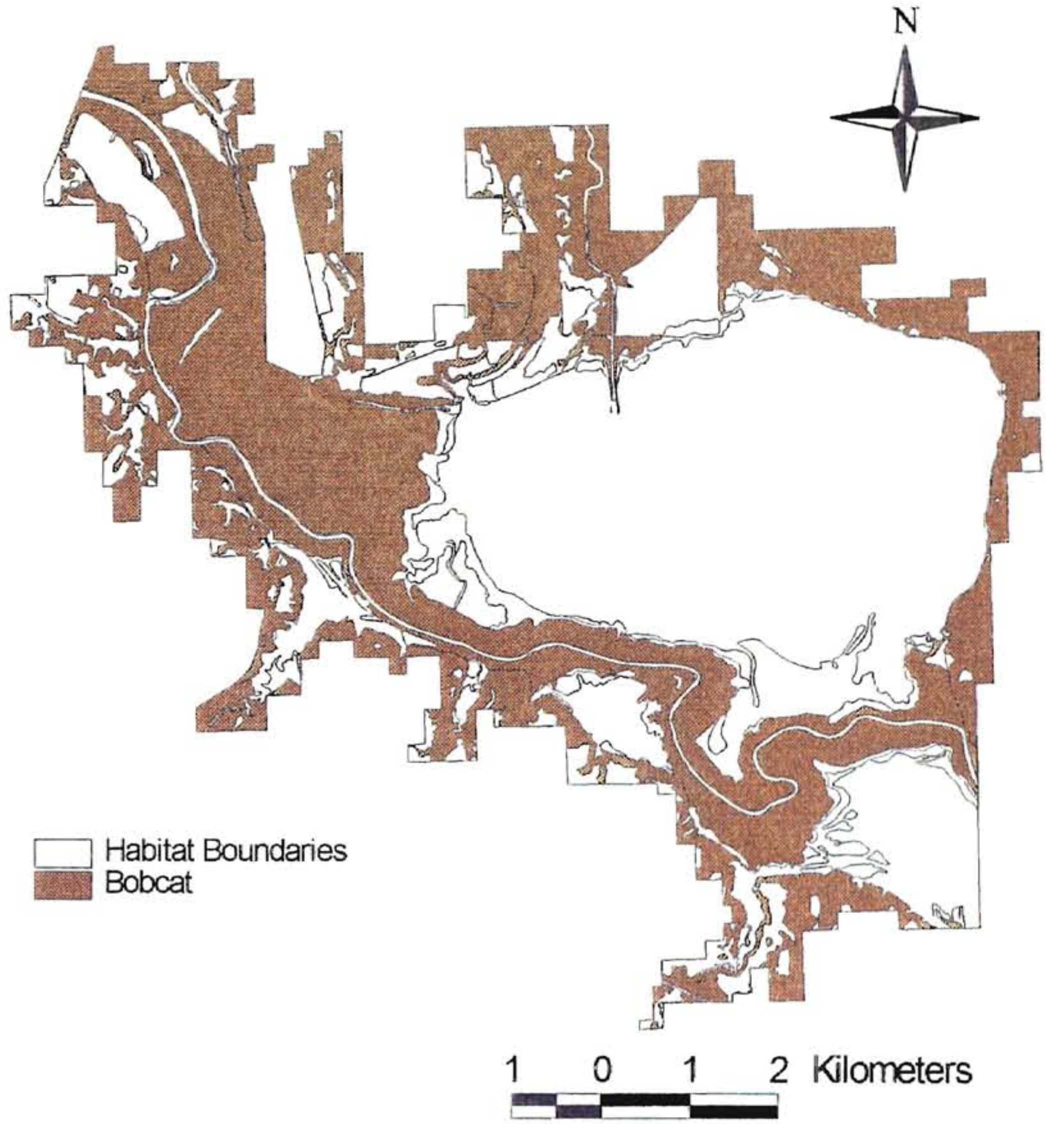


Figure 4

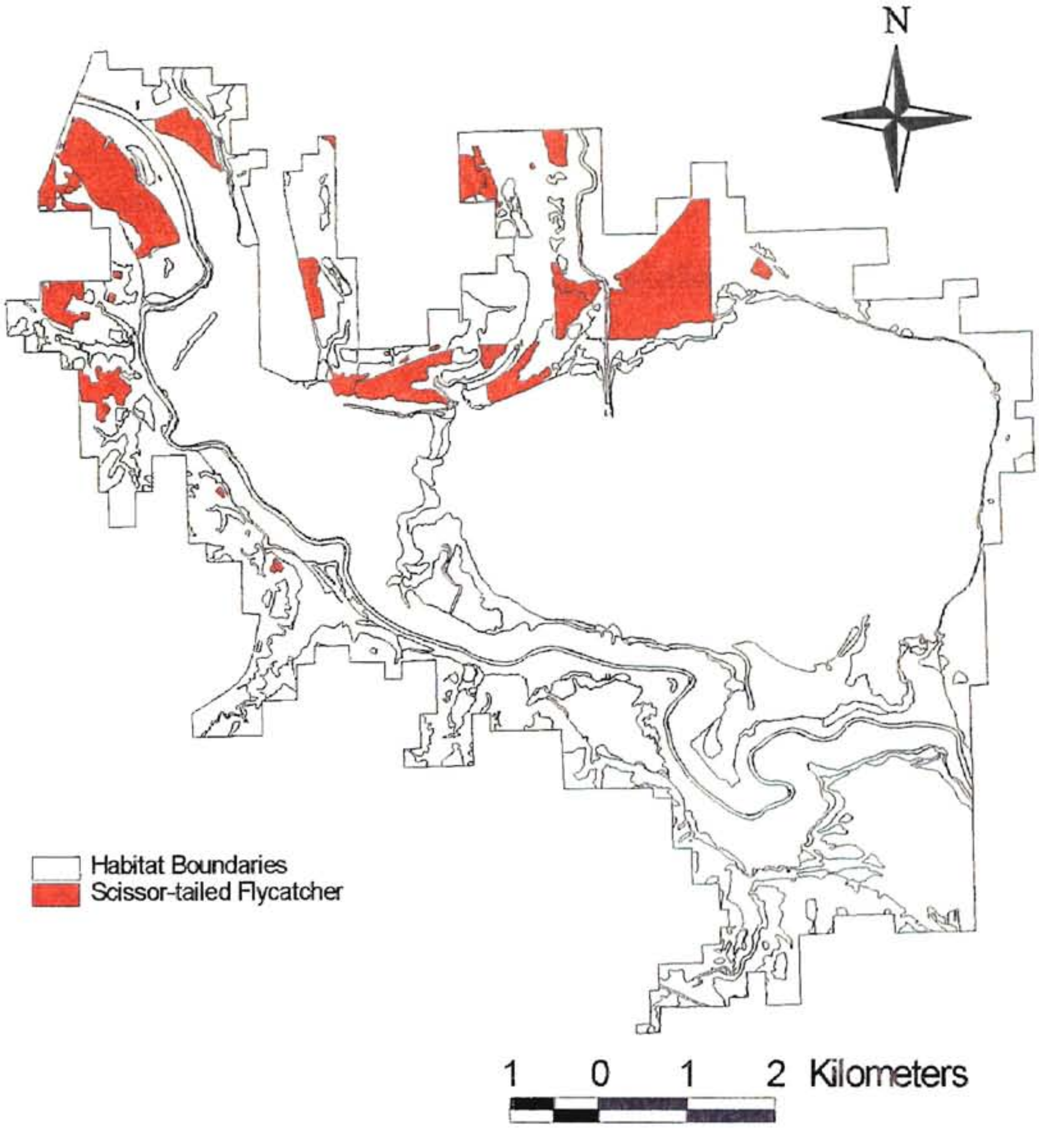

N
Habitat Boundaries
Scissor-tailed Flycatcher
1 0 1 2 Kilometers

Figure 5

CHAPTER III

AVIAN COMMUNITY STRUCTURE OF THE FLOODPLAIN ALONG THE WASHITA RIVER, OKLAHOMA

ABSTRACT--We studied avian community composition of the floodplain along the Washita River, Oklahoma, from fall 1996 through summer 1997. Historically, siltation of the Washita River has created new lowland habitat. We described avian community structure and identified the effect of season and habitat type on the avian community. We used canonical correspondence analysis to examine relationships between bird community structure and environmental gradients. We counted 71 bird species and found avian diversity to be highest in the lowland habitat. Species composition was related to seasonal effects ($\underline{F} = 3.45$, $\underline{P} < 0.001$) and habitat type when seasonal effects were factored out ($\underline{F} = 2.15$, $\underline{P} < 0.001$). The creation of the lowland habitat affected avian species composition along the Red River.

Ecological communities are in a perpetual state of flux and change daily, seasonally, and annually in species abundance and composition (Raitt and Pimm, 1976). Communities develop through many processes in a sequence of community states. Each state is a unique combination of species' presence or absence (Luh and Pimm 1993) and thus has different structure. Previous studies have related avian community structure to habitat variables such as vegetative structure (MacArthur and MacArthur, 1961; MacArthur, 1964; Karr and Roth, 1971; Holmes et al. 1979). Other studies have not found strong relationships between vegetative structure and avian diversity (Tomoff, 1974; Willson, 1974; Roth, 1976). The avian community in any given habitat is not static but changes seasonally (Avery and van Riper, 1989).

Avian community composition changes with different disturbances (Wiens 1989). Terborgh et al. (1997) studied effects of a hydroelectric impoundment and the creation of islands on bird communities and found that changes in species composition occurred due to biological and stochastic processes. Croonquist and Brooks (1993) described effects of habitat disturbance in riparian corridors. They found that different sizes of riparian areas affected species composition differently. Bollinger (1995) studied effects of successional changes in vegetation of agricultural hayfields on bird communities and found that vegetative structure, composition, and patch size were the most important in habitat selection by bird species. We studied the effect of a newly formed habitat on a bird community in south-central Oklahoma by analyzing the current community.

Tishomingo National Wildlife Refuge (NWR) along the dissected coastal plain of the Red River has undergone dynamic changes in physical and biological resources since its creation in 1946. Siltation from the Washita River has formed a delta of about 1,012 ha that contains mostly willow (Salix spp.) and cottonwood (Populus deltoides). This area was part of Lake Texoma before the new habitat was formed. Creation of this habitat type likely has affected structure of the bird community at Tishomingo NWR.

We described bird community structure of Tishomingo NWR and identified environmental variables that relate to avian species composition. We described species composition for different habitat types and identified species that were strongly associated with the delta. We reasoned that historically those species were not present on the refuge.

MATERIAL AND METHODS--The study was conducted on the 6,669-ha Tishomingo NWR located in south-central Oklahoma along the floodplain of the Washita River (34°10′N, 96°40′W). The refuge consisted of both the Midgrass Eroded Plains Vegetation Type and Post Oak-Blackjack Forest Type (Duck and Fletcher, 1943). Principal woody species were blackjack oak (Quercus marilandica), winged elm (Ulmus alata), osage-orange (Maclura pomifera), chickasaw plum (Prunus angustifolia), and persimmon (Diospyros virginiana). Bottomlands were a dense stand of willow (Salix spp.) with some cottonwood (Populus deltoides). Dominant grasses included little bluestem (Andropogon scoparius), broomsedge bluestem (A. virginicus), and Indian grass (Sorghastrum nutans). Botanical nomenclature followed Great Plains Flora Association (1986).

Tishomingo NWR was located just north of Lake Texoma, and the Washita River flows through it into Lake Texoma. Lake Texoma was created in 1937 with the construction of the Denison Dam. Since 1937, the Washita River has formed 1,012-ha delta in Tishomingo NWR and created the 1,821-ha Cumberland Pool of Lake Texoma. The Cumberland Pool is located entirely within Tishomingo NWR. Siltation from the Washita River has cut off the Cumberland Pool from Lake Texoma. During flood stages, the river spills into the pool, depositing silt and increasing the size of the delta. When the water is <189 m above mean sea level (msl), mudflats are exposed. The Cumberland Pool was a shallow sloping basin with mudflats to the south and west. Refuge managers have no control over the water level of the Cumberland Pool because it is under the jurisdiction of the U.S. Army Corps of Engineers (Draft Master Plan 1990, Tishomingo National Wildlife Refuge).

We delineated habitat types from 1991 aerial photography (Tishomingo National Wildlife Refuge, Tishomingo, OK). Five habitat types were identified that represented the majority (95%) of terrestrial habitat types on the refuge (Table 1). The refuge was 56% terrestrial and 44% aquatic. Our wetland habitat type was included to represent birds that were associated with water. The 4 other habitat types represented different structure and vegetative species (Table 1). The willow-cottonwood forest was seasonally flooded and was covered with woody debris. We groundtruthed all habitat types by hiking through the area and confirming the habitat types.

We established 36 survey points within each habitat type. Points were established in each habitat type such that they were >100 m from adjacent habitats. Survey points were >60 m from each other (Schulz et al., 1992). In each habitat, we randomly selected and sampled 6 points/season. Birds surveyed ≤100 m of the survey point were used in this study. Flying birds were not included. We spent 10-min at each station with a 1-min waiting period before observations began (Avery and van Riper, 1989; Schulz et al., 1992). We identified species by sight, sound, call or any combination of those cues (Emlen, 1977). We performed surveys between sunrise and 4 hours after sunrise to survey the maximum number of birds (Shields, 1977; Robbins, 1981). Surveys were performed only when weather met the following criteria: no rain, no fog, and wind below a gust (Robbins, 1981). We surveyed birds in fall 1996 (October 5, 12, and 19), winter 1997 (January 18, 25, and February 8), spring 1997 (May 3, 4, 14, and 15), and summer 1997 (July 24, 25, and 26).

We measured environmental variables at every survey point using different methods and sources. Seasons and habitat types were entered as dummy (0,1) environmental variables. To measure vegetation structure, we used the point-quarter method (Brower et al., 1990) for plants in the 1-5 m and >5 m strata. The point-quarter method provided diameter at breast height (dbh) and an index of vegetation density (Brower et al., 1990). Height of each plant used in the point-quarter method was recorded. Canopy cover was estimated by averaging 4 readings (N, S, E, W) of a densiometer (Lemmon 1957) at each survey point. We also recorded presence or absence of the following habitat features: rocks, boulders, ledges, logs, leaf litter, vines, woody debris, snags, herbaceous vegetation, and water. Temperature, humidity, solar radiation, and wind speed were attained from the Oklahoma Mesonet (Oklahoma Climatological Survey, Norman, OK). Those weather data were recorded 9.6 km north of Tishomingo NWR.

To describe avian community types, we calculated bird species richness, evenness, and diversity (Brower et al., 1990; Cotgreave and Harvey, 1994) for each habitat type within each season. We grouped avifauna into migration groups (Peterjohn and Sauer, 1993; Table 2). Species richness was the number of species surveyed. Evenness was calculated as the frequency of observations by species (Pielou, 1966; Brower et al. 1990). We compared richness and evenness among habitats and seasons using the Kruskal-Wallis test (Zar, 1984). When significant differences occurred multiple comparisons were calculated using LSD analysis (Zar, 1984). We calculated diversity using Simpson's diversity index (Simpson, 1949), which is an expression of the probability that two individuals drawn at random from a community belonged to different species (Hurlbert, 1971). All statistical tests were performed with an alpha level of 0.05.

We used canonical correspondence analysis (CCA; ter Braak, 1986) to examine relationships between bird community structure and environmental gradients. CCA is a direct gradient analysis technique in which species composition is related directly to environmental variables (ter Braak, 1986; Palmer, 1993). We used partial ordination to examine effects of environmental variables without the effect of other variables (ter Braak, 1988; Palmer, 1993). Species data were square-root transformed and down-weighted to dampen effects of rare species (ter Braak 1987).

Correspondence analysis is sensitive to rare species (ter Braak 1988). First, we examined effects of season on bird composition. Then, we examined effects of habitat type including season variables as covariables. Finally, we examined effects of weather variables and habitat structure on species composition using forward selection with the Monte Carlo method (ter Braak, 1988), including season and habitat type as covariables. The significance of those 4 sets of environmental variables was tested using the Monte Carlo permutation method (ter Braak, 1988). One thousand random permutations were used for each Monte Carlo analysis. The resulting ordination showed the relationship between species abundance and environmental variables (ter Braak, 1986; Palmer, 1993). CCA was performed using Canoco For Windows version 4.0 (ter Braak and Smilauer, 1997).

RESULTS--Seventy-one species were encountered at Tishomingo NWR from fall 1996 through summer 1997 (Table 2). Forty-one species were short distance migrants, 21 species were neotropical migrants, and 9 species were permanent residents (Table 2).

There was no difference between ranks of richness scores of seasons ($F = 2.54$, d.f. = 3, $P = 0.1056$). There was a difference in the richness scores of habitat types ($F = 6.03$, d.f. = 4, $P = 0.0067$). Field-shrub differed in richness from upland habitat but not the other 3 habitats (F = 6.03, d.f. = 4, P = 0.0067). Lowland differed in richness from wetland and woodland habitats (F = 6.03, d.f. = 4, P = 0.0067) but not from field-shrub or upland habitat types. Richness in upland differed from all habitats except lowland (F = 6.03, d.f. = 4, P = 0.0067). Richness in wetland habitat differed from the upland and lowland habitats (F = 6.03, d.f. = 4, P = 0.0067). Wetland habitat had the most species present while woodland, field-shrub, lowland, and upland had ascending number of species, respectively (Fig. 1).

We found no significant difference in evenness scores among seasons or habitat types. Evenness values ranged from 0.56 in the winter to 0.94 in the spring. Evenness values ranged from 0.54 in the wetland habitat to 0.92 in the lowland habitat (Fig. 2). The survey that resulted in the lowest evenness seasonally (0.56) and by habitat (0.54) was deleted from ordination analysis because >200 waterfowl were observed, which was unusual.

Species diversity values ranged from 0.71 in winter to 0.96 in spring. Diversity values ranged from 0.72 in the wetland habitat to 0.94 in the lowland habitat (Fig. 3). Although no difference in diversity among season or habitats were found, indices in winter and the wetland habitat were reduced because of the large number of waterfowl in a couple of samples.

Species composition was related to seasonal effects (F = 3.45, P < 0.001). Our results showed the relationship of some species to seasons along the first two CCA axes (Fig. 4), but those axes explained only about 9% of the total variation in species abundance. Although only 9% of variation was explained, axes were still interpretable as an effect of season. The centroid for each season was located in a separate corner of the biplot with corresponding species located close to the seasonal centroid (Fig. 4). Species located in the center of the diagram were found in most seasons, but species located closer to the centroid of a particular season had a stronger relation to that season. Indigo bunting (*Passerina cyanea*), field sparrow (*Spizella pusilla*), and ruby-throated hummingbird (*Archilochus colubris*) are all neotropical migrants, and they were associated with the spring season (Table 2; Fig. 4). Most species associated with winter (yellow-rumped warbler [*Dendroica coronata*], song sparrow [*Melospiza melodia*], and downy woodpecker [*Picoides pubescens*]) were all either short distance migrants or permanent residents (Table 2; Fig. 4).

Species composition was related to habitat type when seasonal effects were factored out (F = 2.15, P < 0.001). The first 2 CCA axes (Fig. 5) explained about 8% of the total variation in species abundance and were a function of habitat type (Fig. 5). The closer a species was to a habitat type, the stronger the association of that species and habitat type (Fig. 5). Species that are associated with open habitats, such as field sparrow (Spizella pusilla), painted bunting (Passerina ciris), indigo bunting (P. cyanea)(Peterjohn and Sauer, 1993), were associated with the field-shrub and woodland habitat types. wood duck (Aix sponsa) and bald eagle (Haliaeetus leucocephalus) were strongly associated with the wetland habitat type. Downy woodpecker (Picoides pubescens) and white-breasted nuthatch (Sitta carolinensis) were associated with the lowland habitat.

Weather variables were not related to species composition with habitat types and seasons as covariables ($F = 1.34$, $P = 0.87$). Also, variables of habitat structure were not related with habitat types and seasons as covariables ($F = 1.77$, $P = 0.44$).

DISCUSSION--Seasons--Migration caused a seasonal shift in the avian community structure of Tishomingo NWR. Migration is a response to changes in the environment (Welty and Baptista 1988). This response is a complex system that results in the avoidance of harsh environmental conditions and exploitation of beneficial conditions (Terrill, 1988).

Studies have reported changes in avian diversity with a change in season (Rabenold,1978; Holmes and Sturges, 1975). Rabenold (1978) suggested that seasonality enhanced diversity of birds. Holmes and Sturges (1975) found a greater diversity of birds in summer compared with winter in a hardwood forest. Our results also show higher diversity in summer than winter, but our highest diversity occurred in spring (Fig. 3).

In addition to change in diversity between seasons, species composition of the refuge changed among seasons (Fig. 4). Avian communities in temperate regions are comprised of resident species complemented by migratory species that combine to form varying communities throughout the year (Anderson, 1972; Avery and van Riper, 1989). We found this to be true at Tishomingo NWR. Neotropical migrants leave the refuge in winter due to environmental conditions (Terrill, 1988), and short distance migrants move into the refuge for fall or winter.

Habitat--Effects of habitat and vegetative structure on avian communities have been the focus of many studies (MacArthur, 1961; MacArthur, 1964; Karr and Roth, 1971; Willson, 1974; Holmes et al., 1979; James and Wamer, 1982; Urban and Smith, 1989; Naranjo and Raitt, 1993). MacArthur (1962) and Willson (1974) suggested that habitats with more trees and vegetative variation contained a greater number of bird species. Others suggested that species richness is not highest in areas of high tree density (James and Wamer, 1982). Our variables of habitat structure were not related to species composition.

Evenness of abundance in bird communities tends to vary with habitat type and number of species (Cotgreave and Harvey, 1994). Although we found no significant difference in the evenness scores of habitats, the lowland habitat was consistently higher in evenness than other habitats (Fig. 2). The lowland habitat had a pattern of avian abundance that suggested a more complex habitat. Communities in a more complex habitat have more even abundance distributions (Cotgreave and Harvey, 1994). Cotgreave and Harvey (1994) suggested that complex habitats have many niches with a wide variety of food and nest sites.

Historic Change of Habitat--Given that lowland habitat was virtually nonexistent at Tishomingo NWR in 1946, siltation by the Washita River has changed the physical structure of the refuge. The effect of the addition of the 1,012-ha lowland habitat on avian diversity on the refuge can be examined in the CCA. If the lowland habitat was removed, many species associated with that habitat also would be removed. Winter Wren (*Troglodytes troglodytes*), Swainson's Warbler (*Limnothlypis swainsonii*), and Brown Creeper (*Certhia americana*) were found in only the lowland habitat. Other species such as Gray Catbird (Dumtella carolinensis) and the White-breasted Nuthatch (Sitta carolinensis) were associated strongly with the lowland habitat (Fig. 5). Lowland habitat had the highest diversity of all habitats. We propose that siltation by the Washita River and formation of the delta has increased species richness on Tishomingo NWR.

Conclusion--Seasons and different habitats affect composition of avian species at Tishomingo NWR. Weather and habitat structure do not seem to explain any additional variation in bird species composition. These results help us to examine what might happen to community structure given a change a habitat. Management of TNWR could use such an analysis to predict what species may be affected by ongoing management practices and future management goals.

Acknowledgments--We thank the Trust for Public Land, Tishomingo National Wildlife Refuge, and the Oklahoma Cooperative Fish and Wildlife Research Unit (Oklahoma Department of Wildlife Conservation, Oklahoma State University, U.S. Geological Survey Biological Resources Division, and Wildlife Management Institue, cooperating) for financial and logistical support. We would also like to acknowledge our technicians, S. Larrabee and J. Webster. Special thanks to M. Palmer for helping with the analyses.

LITERATURE CITED

American Ornithologists' Union. 1983. Check-list of North American birds, 6th edition. Allen Press, Lawrence, Kansas, 877pp.

Anderson, S. H. 1972. Seasonal variation in forest birds of western Oregon. Northwest Science, 46:194-206.

Avery, M. L., and C. van Riper III. 1989. Seasonal changes in bird communities of the chaparral and blue-oak woodlands in central California. Condor, 91:288-295.

Bollinger, E. K. 1995. Successional changes and habitat selection in hayfield bird communities. Auk 112:720-730.

Brower, J. E., J. H. Zar, and C. N. von Ende. 1990. Field and laboratory methods for general ecology. Third ed. Wm. C. Brown Publishers, Dubuque, 237 pp.

Cotgreave, P., and P. H. Harvey. 1994. Evenness of abundance in bird communities. Journal of Animal Ecology, 63:365-374.

Croonquist, M. J. and R. P. Brooks. 1993. Effect of habitat disturbance on bird communities in riparian corridors. J. Soil and Water Cons. 48:65-70.

Duck, L. G., and J. B. Fletcher. 1943. A game type map of Oklahoma. Oklahoma Game and Fish Dept., Oklahoma City.

Emlen, J. T. 1977. Estimating breeding season bird densities from transect counts. Auk, 94:455-468.

Great Plains Flora Association. 1986. Flora of the Great Plains. University Press of Kansas. Lawrence, Kansas, 1392 pp.

Holmes, R.T., and F. W. Sturges. 1975. Bird community and energetics in a northern hardwoods ecosystem. Journal of Animal Ecology, 44:175-200.

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.

Hurlbert, S. H. 1971. The nonconcept of species diversity: a critique and alternative parameters. Ecology, 52:577-586.

James, F. C., and N. O. Wamer. 1982. Relationships between temperature forest bird communities and vegetation structure. Ecology, 63:159-171.

Karr, J. R., and R. R. Roth. 1971. Vegetation structure and avian diversity in several New World areas. American Naturalist, 105:423-435.

Lemmon, P. E. 1957. A new instrument for measuring forest overstory density. Journal of Forestry, 55:667-669.

Luh, H., and S. L. Pimm. 1993. The assembly of ecological communities: a minimalist approach. Journal of Animal Ecology, 62:749-765.

MacArthur, R. H. 1964. Environmental factors affecting bird species diversity. American Naturalist, 98:387-397.

MacArthur, R. H., and J. W. MacArthur. 1961. On bird species diversity. Ecology, 42:594-598.

Naranjo, L. G., and R. J. Raitt. 1993. Breeding bird distribution in Chihuahuan Desert habitats. The Southwestern Naturalist, 38:43-51.

Palmer, M. W. 1993. Putting things in even better order: the advantages of canonical correspondence analysis. Ecology, 74:2215-2230.

Peterjohn, B. G., and J. R. Sauer. 1993. North American Breeding Bird Survey annual summary 1990-1991. Bird Populations, 1:1-24.

Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. Journal of Theoretical Biology 13:131-144.

Rabenold, K. N. 1978. Foraging strategies, diversity, and seasonality in bird communities of Appalachian spruce-fir forests. Ecological Monographs, 48:397-424.

Raitt, R. J., and S. L. Pimm. 1976. Dynamics of bird communities in the Chihuahuan Desert, New Mexico. Condor, 78:427-442.

Robbins, C. S. 1981. Effect of time of day on bird activity. In: Estimating Numbers of Terrestrial Birds. Cooper Ornithological Society, Lawrence, Kansas.

Roth, R. R. 1976. Spatial heterogeneity and bird species diversity. Ecology, 57:773-782.

Schulz, C. A., D. M. Leslie, Jr., and R. L. Lochmiller. 1992. Autumn and winter bird populations in herbicide-treated cross timbers in Oklahoma. American Midland Naturalist 127:215-223.

Shields, W. M. 1977. The effect of time of day on avian census results. Auk, 94:380-383.

Simpson, E. H. 1949. Measurement of diversity. Nature, 163:688.

ter Braak, C. J. F. 1986. Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology, 67:1167-1179.

ter Braak, C. J. F. 1987. Ordination. In Data Analysis In Community and Landscape Ecology (Ed. R.H.G. Jongman, C. J. F. ter Braak, and O. F. R. van Tongeren), pp.91-173. Pudoc, Wageningen.

ter Braak, C. J. F. 1988. Partial canonical correspondence. In Classification and Related Methods of Data Analysis (Ed. H. H. Bock), pp.551-558. Elsevier Science Publishers, Amsterdam.

ter Braak, C. J. F., and P. Smilauer. 1997. Canoco 4.0 for Windows.

Terborgh, J., L. Lopez, and J. Tello S. 1997. Bird communities in transition: the Lago Guri islands. Ecology, 78:1494-1501.

Terrill, S. B. 1988. The relative importance of ecological factors in bird migration. Pp. 2180-2190, in Acta XIX Congressus Internationalis Ornithologici (Henri Ouellet, ed.). University of Ottawa Press, Canada, 3455pp.

Tomoff, C. S. 1974. Avian species diversity in desert scrub. Ecology, 55:396-403.

Urban, D. L., and T. M. Smith. 1989. Microhabitat and the structure of forest bird communities. The American Naturalist, 133:811-829.

Welty, J. C., and L. Baptista. 1988. The life of birds, 4th edition. Saunders College Publishing, New York. 581pp.

Weins, J. A. 1989. The ecology of bird communities: v. 2. processes and variations. Cambridge University Press, New York. 319pp.

Willson, M. F. 1974. Avian community organization and habitat structure. Ecology, 55:1017-1029.

Zar, J. H. 1984. Biostatistical Analysis. 2d ed. Prentice-Hall, Englewood Cliffs, NJ, 718 pp.

Table 1--Canopy cover, strata, area and percent area of the refuge for 5 habitat types delineated for Tishomingo National Wildlife Refuge from 1991 aerial photography.

Habitat	Canopy Cover (%)	Stratum (m)	Area (ha)	Area (%)
Field/shrub[1]	0-60	0-5	541.4	9
Oak-Hickory Forest	61-100	>5	1,454.4	23
Willow-Cottonwood Forest	61-100	>5	1,307.4	20
Oak Woodland	25-60	>5	280.3	4
Wetland[2]	0-100	>0	-	-

[1]Habitat type was combined from field and shrub habitat types to represent habitats of TNWR.

[2]Habitats were considered wetland when they were located on permanent bodies of water.

Table 2--Avian species sampled at Tishomingo National Wildlife Refuge, Oklahoma, fall 1996-summer 1997.

Common name	Scientific name	Migration[1]	Code[2]
American Coot	*Fulica americana*	SDM	AMCO
American Crow	*Corvus brachyrhynchos*	SDM	AMCR
American Goldfinch	*Carduelis tristis*	SDM	AMGO
American Kestrel	*Falco sparverius*	SDM	AMKE
American Robin	*Turdus migratorius*	SDM	AMRO
Bald Eagle	*Haliaeetus leucocephalus*	SDM	BAEA
Barn Swallow	*Hirundo rustica*	NM	BRSW
Belted Kingfisher	*Ceryle alcyon*	SDM	BEKI
Bewick's Wren	*Thryomanes bewickii*	SDM	BEWR
Blue Grosbeak	*Guiraca caerulea*	NM	BLGR
Blue Jay	*Cyanocitta cristata*	SDM	BLJA

Table 2. Continued.

Common name	Scientific name	Migration[1]	Code[2]
Blue-gray Gnatcatcher	Polioptila caerulea	NM	BGGN
Brown Creeper	Certhia americana	SDM	BRCR
Brown Thrasher	Toxostoma rufum	SDM	BRTH
Brown-headed Cowbird	Molothrus ater	SDM	BHCO
Canada Goose	Branta canadensis	SDM	CAGO
Carolina Chickadee	Parus carolinensis	PR	CACH
Carolina Wren	Thryothorus ludovicianus	PR	CAWR
Cattle Egret	Bubulcus ibis	SDM	CAEG
Chimney Swift	Chaetura pelagica	NM	CHSW
Common Grackle	Quiscalus quiscula	SDM	COGR
Dark-eyed Junco	Junco hyemalis	SDM	DEJU

Table 2. Continued.

Common name	Scientific name	Migration[1]	Code[2]
Dickcissel	*Spiza americana*	NM	DICK
Downy Woodpecker	*Picoides pubescens*	PR	DOWO
Eastern Bluebird	*Sialia sialis*	SDM	EABL
Eastern Kingbird	*Tyrannus tyrannus*	NM	EAKI
Eastern Phoebe	*Sayornis phoebe*	SDM	EAPH
Field Sparrow	*Spizella pusilla*	SDM	FISP
Fish Crow	*Corvus ossifragus*	SDM	FICR
Fox Sparrow	*Passerella iliaca*	SDM	FOSP
Gray Catbird	*Dumetella carolinensis*	NM	GRCA
Great Blue Heron	*Ardea herodias*	SDM	GBHE
Great Crested Flycatcher	*Myiarchus crinitus*	NM	GCFL

Table 2. Continued.

Common name	Scientific name	Migration[1]	Code[2]
Greater White-fronted Goose	*Anser albifrons*	SDM	GWFG
Indigo Bunting	*Passerina cyanea*	NM	INBU
Killdeer	*Charadrius vociferus*	SDM	KILL
Loggerhead Shrike	*Lanius ludovicianus*	SDM	LOSH
Mallard	*Anas platyrhynchos*	SDM	MALL
Mourning Dove	*Zenaida macroura*	SDM	MODO
Northern Bobwhite	*Colinus virginianus*	PR	NOBO
Northern Cardinal	*Cardinalis cardinalis*	PR	NOCA
Northern Flicker	*Colaptes auratus*	SDM	NOFL
Northern Shoveler	*Anas clypeata*	SDM	NOSH
Painted Bunting	*Passerina ciris*	NM	PABU

Table 2. Continued.

Common name	Scientific name	Migration[1]	Code[2]
Pied-billed Grebe	Podilymbus podiceps	SDM	PBGR
Pileated Woodpecker	Dryocopus pileatus	PR	PIWO
Prothonotary Warbler	Protonotaria citrea	NM	PRWA
Purple Martin	Progne subis	NM	PUMA
Red-bellied Woodpecker	Melanerpes carolinus	PR	RBWO
Red-headed Woodpecker	Melanerpes erthrocephalus	SDM	RHWO
Red-tailed Hawk	Buteo jamaicensis	SDM	RTHA
Red-winged blackbird	Agelaius phoeniceus	SDM	RWBL
Rose-breasted Grosbeak	Pheucticus ludovicianus	NM	RBGR
Ruby-throated Hummingbird	Archilochus colubris	NM	RTHU
Scissor-tailed Flycatcher	Tyrannus forficatus	NM	STFL

Table 2. Continued.

Common name	Scientific name	Migration[1]	Code[2]
Snow Goose	*Chen caerulescens*	SDM	SNGO
Snowy Egret	*Egretta thula*	SDM	SNEG
Song Sparrow	*Melospiza melodia*	SDM	SOSP
Swainson's Warbler	*Limnothlypis swainsonii*	NM	SWWA
Yellow-throated Warbler	*Dendroica dominica*	NM	YTWA
Tufted Titmouse	*Parus bicolor*	PR	TUTI
Turkey Vulture	*Cathartes aura*	SDM	TUVU
White-breasted Nuthatch	*Sitta carolinensis*	PR	WBNU
White-throated Sparrow	*Zonotrichia albicollis*	SDM	WTSP
Willow Flycatcher	*Empidonax traillii*	NM	WIFL
Winter Wren	*Troglodytes troglodytes*	SDM	WIWR

Table 2. Continued.

Common name	Scientific name	Migration[1]	Code[2]
Wood Duck	Aix sponsa	SDM	WODU
Yellow Warbler	Dendroica petechia	NM	YEWA
Yellow-billed Cuckoo	Coccyzus americanus	NM	YBCU
Yellow-rumped Warbler	Dendroica coronata	SDM	YRWA
Yellow-throated Vireo	Vireo flavifrons	NM	YTVI

[1]Migratory status: NM = neotropical migrant; PR = permanent resident; SDM = short-distance migrant (from Peterjohn and Sauer, 1993)

[2]Species code from the American Ornithologists' Union (1983)

Fig. 1--Avian richness by habitat within season for species sampled at Tishomingo National Wildlife Refuge, Oklahoma.

Fig. 2--Avian evenness by habitat within season for species sampled at Tishomingo National Wildlife Refuge, Oklahoma.

Fig. 3--Simpson's diversity index by habitat within season for avian species sampled at Tishomingo National Wildlife Refuge, Oklahoma.

Fig. 4--Canonical correspondence analysis of seasons and 32 avian species of Tishomingo National Wildlife Refuge, Oklahoma. Avian codes are explained in Table 2.

Fig. 5—Canonical correspondence analysis of habitats and 32 avian species of Tishomingo National Wildlife Refuge, Oklahoma. Avian codes are explained in Table 2.

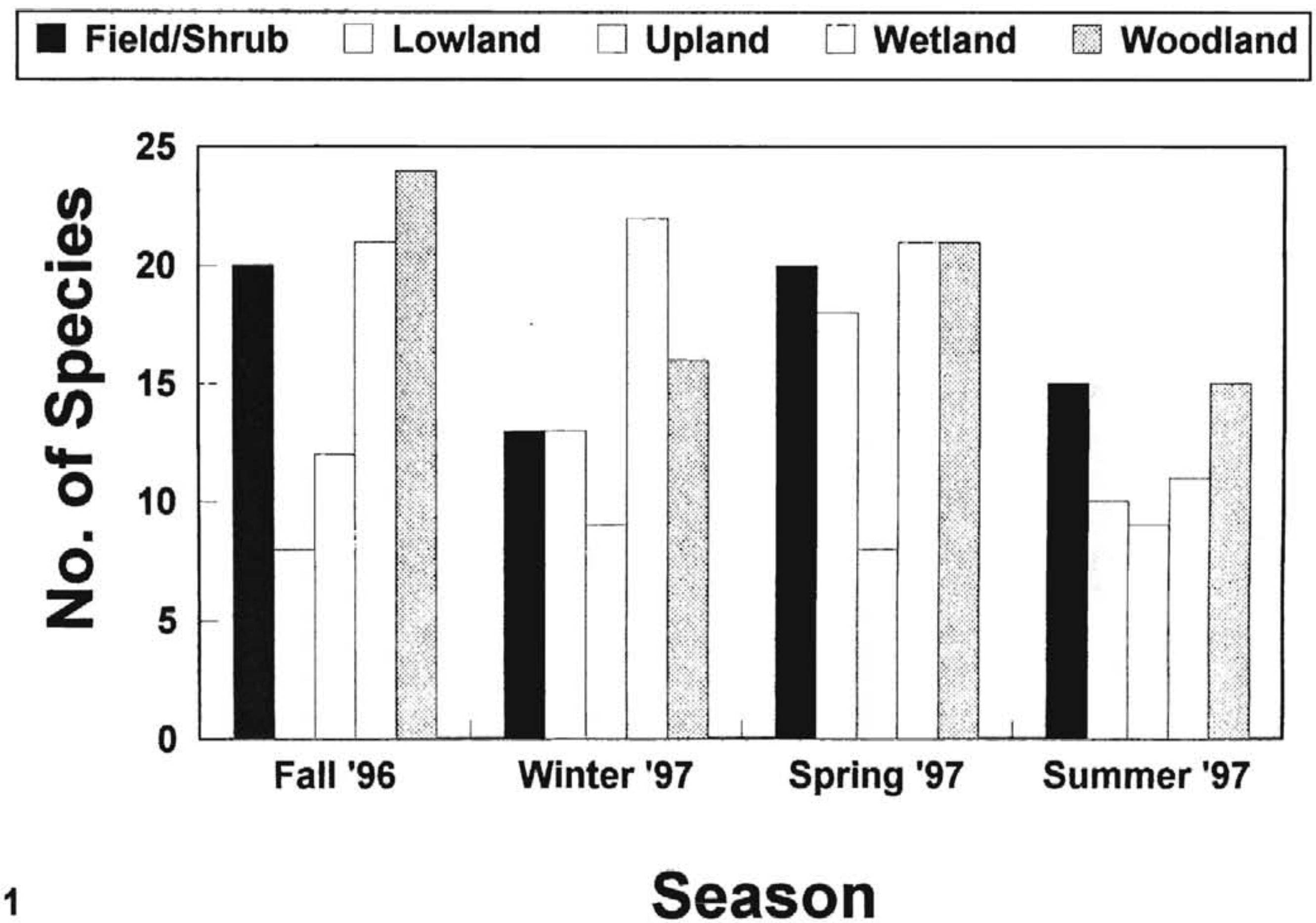

Field/Shrub
Lowland
Upland
Wetland
Woodland
No. of Species
25
20
15
10
5
0
Fall '96
Winter '97
Spring '97
Summer '97
Season

Figure 1

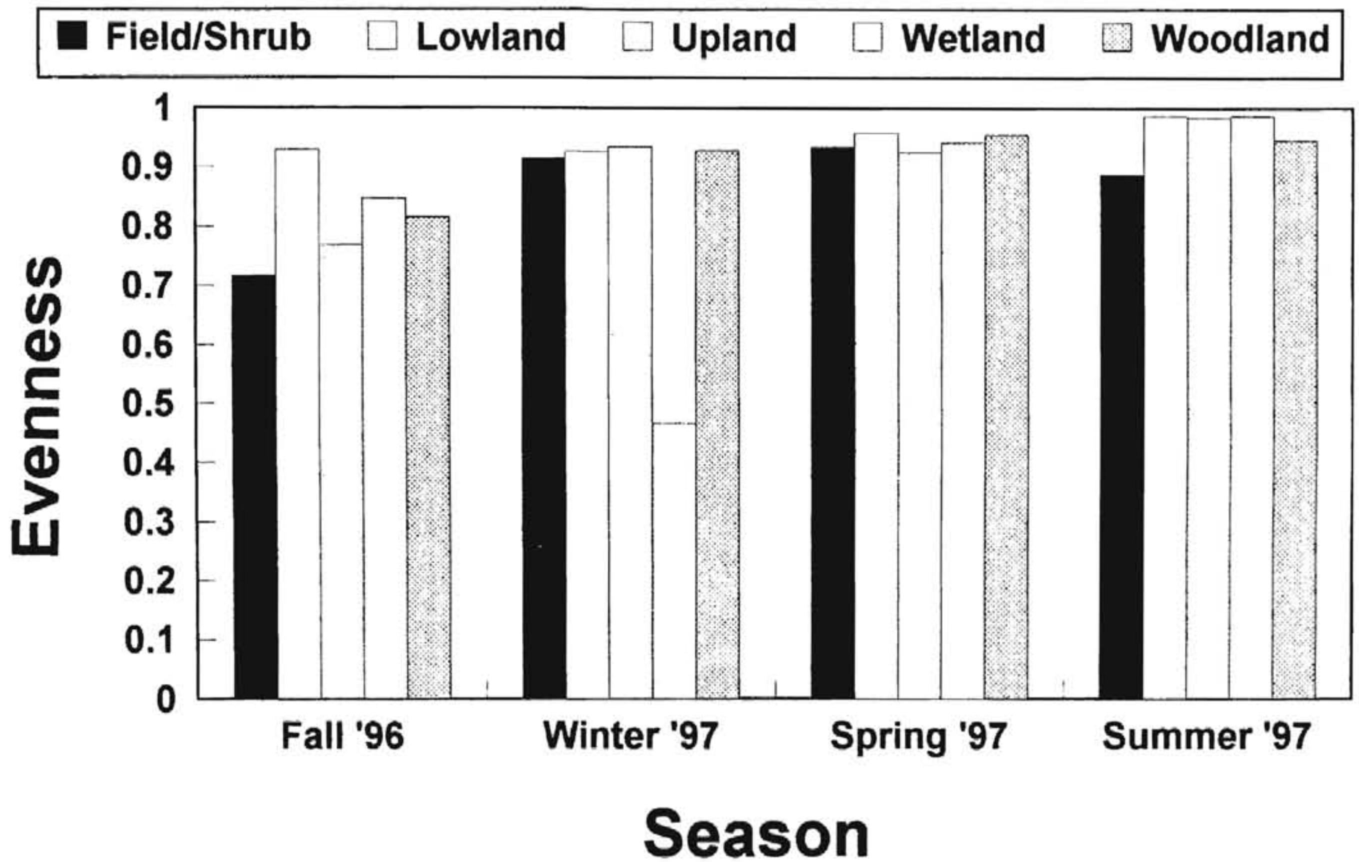

Field/Shrub
Lowland
Upland
Wetland
Woodland
Evenness
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Fall '96
Winter '97
Spring '97
Summer '97
Season

Figure 2

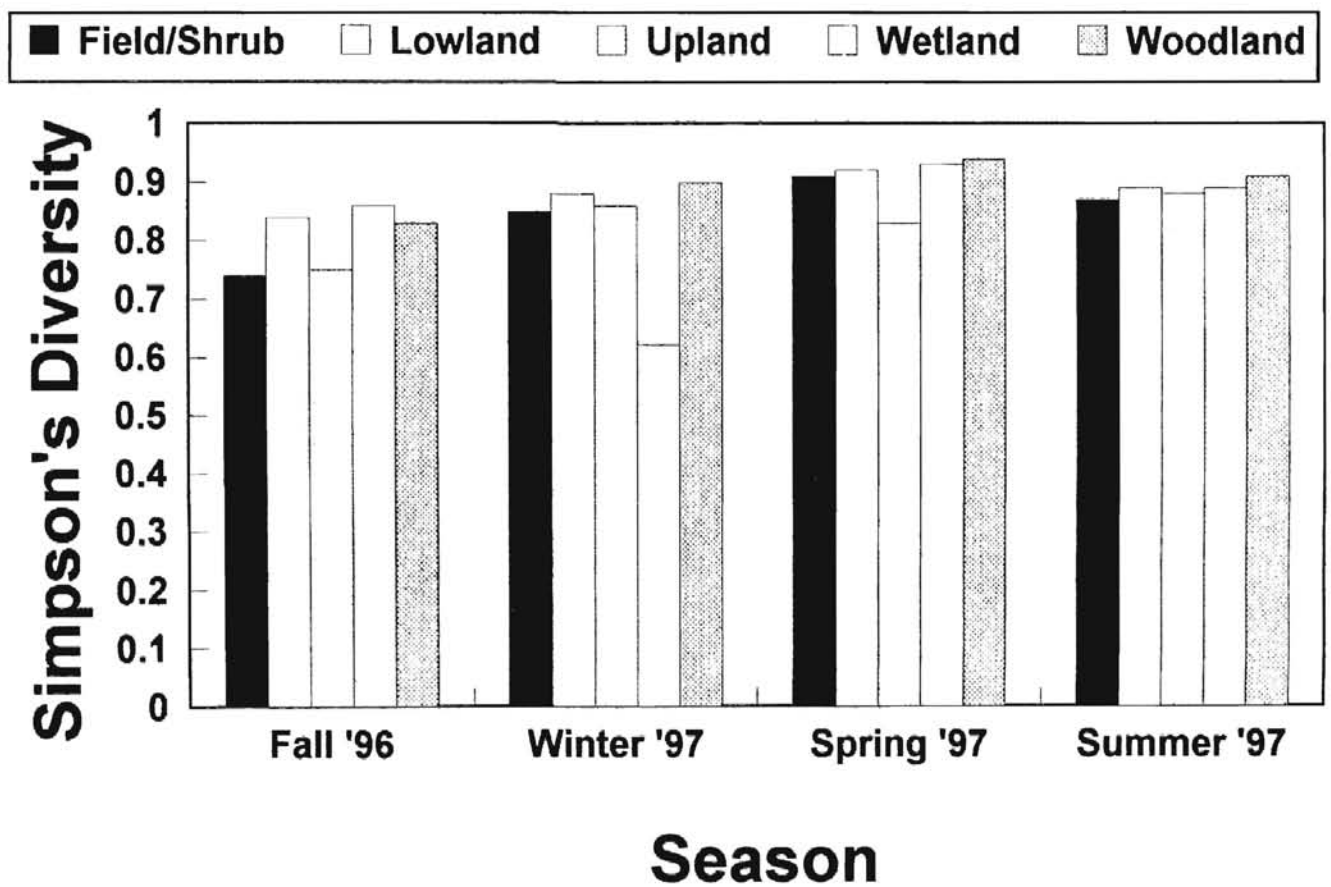
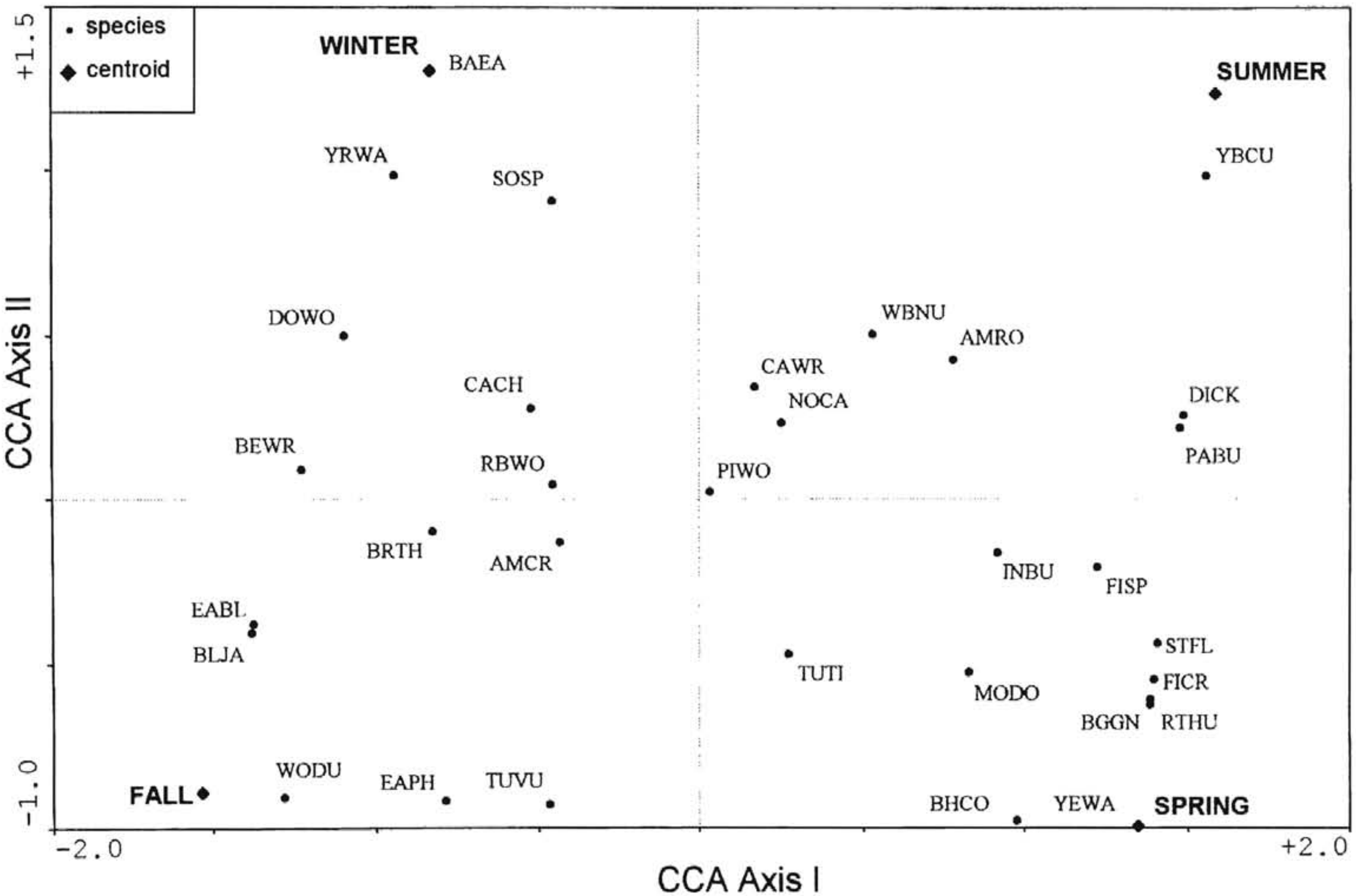

Field/Shrub
Lowland
Upland
Wetland
Woodland
Simpson's Diversity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Fall '96
Winter '97
Spring '97
Summer '97
Season

Figure 3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SUMMER
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CACH
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DICK
PABU
BEWR
RBWO
PIWO
BRTH
AMCR
INBU
FISP
EABL
BLJA
STFL
TUTI
MODO
FICR
BGGN
RTHU
FALL
WODU
EAPH
TUVU
BHCO
YEWA
SPRING
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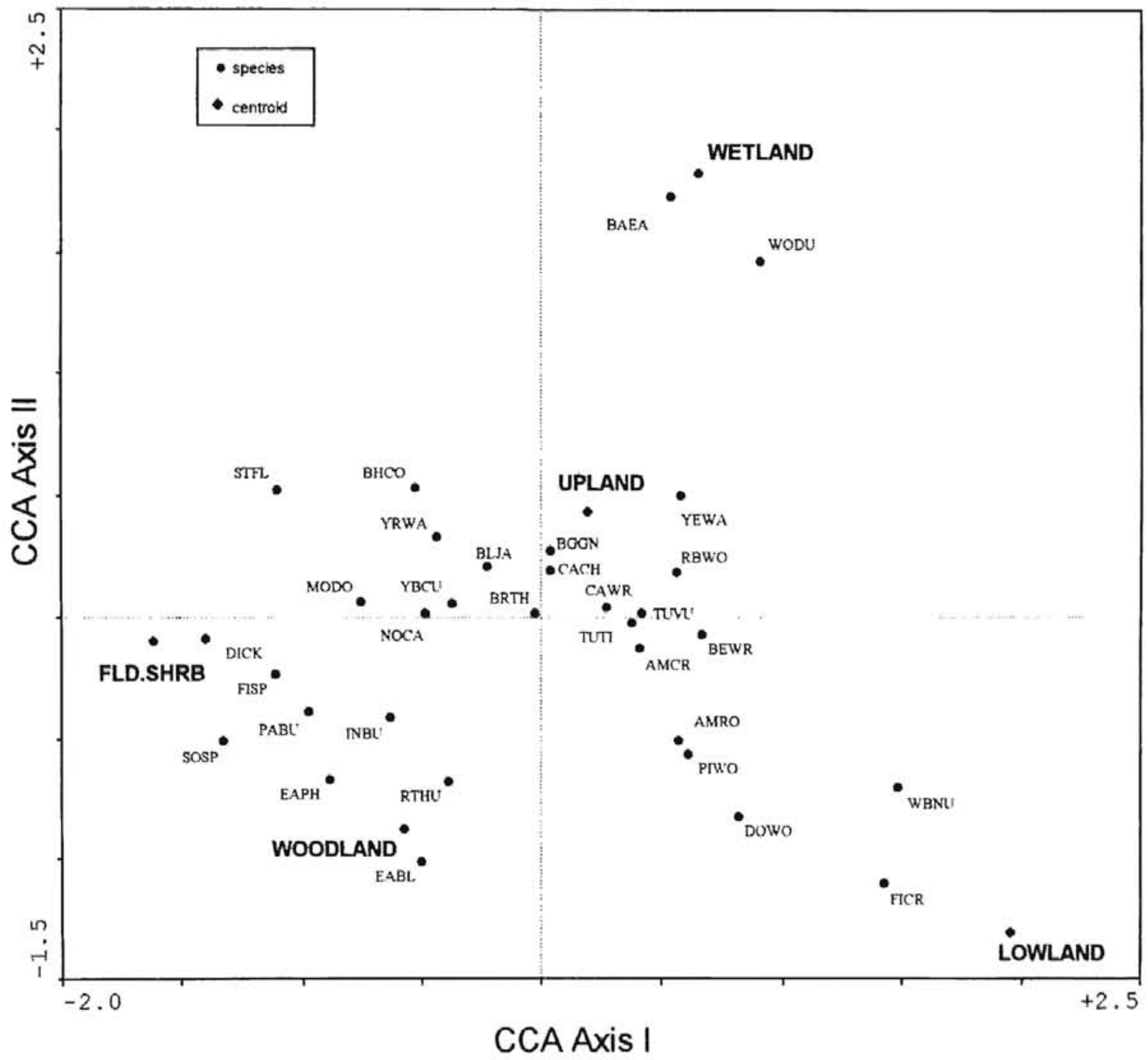
-1.0
-2.0
+2.0
CCA Axis II
CCA Axis I

Figure 4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BRTH
CAWR
TUVU
NOCA
TUTI
BEWR
DICK
AMCR
FLD.SHRB
FISP
AMRO
PABU
INBU
SOSP
PIWO
WBNU
EAPH
RTHU
DOWO
WOODLAND
EABL
FICR
LOWLAND
+2.5
-1.5
CCA Axis II
-2.0
+2.5
CCA Axis I

Figure 5

CHAPTER IV

HABITAT USE OF SHOREBIRDS AT A STOPOVER SITE IN THE SOUTHERN GREAT PLAINS

Abstract.—We studied habitat use of shorebirds (Charadriiformes) at a wetland experiencing natural fluctuations in water levels located at Tishomingo National Wildlife Refuge (NWR) in the south-central Great Plains. We describe use of macro- (disturbed, deciduous, snags, and mudflat) and microhabitat (dry land, wetland, water) by shorebird groups (small sandpipers, medium sandpipers, yellowlegs, etc.). Water level was correlated with shorebird abundance. The small-sandpiper group comprised 85.9% of the total shorebird community. Shorebirds selected mudflat ($P < 0.05$). All shorebird groups selected water microhabitat, except for the small sandpiper group that selected wetland microhabitat ($P < 0.05$). There was a negative correlation ($r_s = -0.36$, $n = 58$, $P = .005$) between pool level and number of shorebirds per survey. The relationship of water level and bird abundance may have more of an impact in an unmanaged wetland than managed wetlands. Tishomingo NWR may be an important stopover site for small sandpipers, such as Western Sandpipers (*Calidris mauri*), that require many stops along their migration routes.

A shorebird's annual cycle consists of 3 phases: breeding, migration, and non-breeding residency (Myers et al. 1987). In spring, shorebirds fly north to the taiga and tundra of the Arctic to breed (Myers 1983). In autumn, they move south to wintering areas in South America (Myers 1983). Major migration routes pass along the Atlantic and Pacific coasts, through South America, the western Gulf of Mexico and the Great Plains of North America (Myers et al. 1987). Tishomingo National Wildlife Refuge (NWR) is a stopover site located in the south-central Great Plains. In each of these migrational routes, shorebirds stop at wetland sites to replenish fat reserves that are used for energy on these long flights (Myers 1983, Myers et al. 1987, Skagen and Knopf 1994a). These fat reserves are essential for migration and breeding (Ashkenazie and Safriel 1979, Hilden 1979, Myers et al. 1987).

Managing water levels can increase the amount of available habitat for shorebirds (Hands et al. 1991, Taylor et al. 1993, Skagen and Knopf 1994b). Water levels at Tishomingo NWR can not be manipulated. Like other wetlands in the Great Plains, water levels at Tishomingo NWR vary seasonally and yearly.

The purpose of this study was to document habitat use of shorebirds in a south-central Great Plains wetland. We assessed the relationship of water level and habitat use of shorebirds where water levels could not be manipulated. We discuss the role of Tishomingo NWR as a stopover site in the Great Plains.

METHODS

Study site.—The study was conducted on the 5,443-ha Tishomingo NWR located in south-central Oklahoma (34°10′N, 96°40′W). The refuge consisted of both the Midgrass Eroded Plains Vegetation Type and Post Oak-Blackjack Forest Type (Duck and Fletcher, 1943). Principal woody species were blackjack oak (Quercus marilandica), winged elm (Ulmus alata), osage-orange (Maclura pomifera), chickasaw plum (Prunus angustifolia), and persimmon (Diospyros virginiana). Bottomlands were a dense stand of willow (Salix spp.) with some cottonwood (Populus deltoides). Dominant grasses included little bluestem (Andropogon scoparius), broomsedge bluestem (A. virginicus), and Indian grass (Sorghastrum nutans). Botanical nomenclature followed the Great Plains Flora Association (1986).

Tishomingo NWR was located just north of Lake Texoma, and the Washita River flowed through it into Lake Texoma. Lake Texoma was created in 1937 with the construction of the Denison Dam. Since 1937, the Washita River has formed a 1,012-ha delta in Tishomingo NWR and created the 1,821-ha Cumberland Pool of Lake Texoma. The Cumberland Pool is located entirely within Tishomingo NWR. Siltation from the Washita River has cut off the Cumberland Pool from Lake Texoma. During flood stages, the river spills into the pool, depositing silt and increasing the size of the delta. When the water is <189 m above mean sea level (msl), mudflats are exposed. The Cumberland Pool was a shallow sloping basin with mudflats to the south and west. Refuge managers have no control over the water level of the Cumberland Pool because it is under the jurisdiction of the U.S. Army Corps of Engineers (Draft Master Plan 1990, Tishomingo National Wildlife Refuge).

Shorebird surveys.—We delineated shoreline habitat types from 1991 aerial photography. Shoreline habitats of the Cumberland Pool were scanned on an Eagle 3640 (ANA Tech, Littleton, CO) flatbed scanner and imported into Arc/Info, version 7.0 (ESRI, Redlands, CA). We measured distance along the shoreline for each habitat type. Four macrohabitats were identified: disturbed, deciduous, snags, and mudflat. These macrohabitats comprised 100% of the shoreline of the Cumberland Pool (Table 1). Disturbed habitat included shoreline used for boat launching, fishing, and other human activities. Disturbed habitat was included because human disturbance can limit the capacity of a staging area to support migrating shorebirds (Pfister et al. 1992). Rocky shorelines with trees made up the deciduous habitat, composed mainly of post oak (Quercus stellata) and blackjack oak. Dead black willow (Salix nigra) and cottonwood trees flooded by the creation of the Cumberland Pool made up the snag habitat. Mudflat habitat consisted of relatively flat areas dominated by mud. Vegetation found on the upland border of mudflats included willow, cottonwood, and buttonbush (Cephalanthus occidentalis). Habitats were groundtruthed, using a boat and aerial photography, prior to surveys of shorebirds.

We surveyed a proportionate sample of each habitat compared with actual shoreline (Table 1). The same observer conducted all surveys with a 15 x 60 variable spotting scope and 8 x 32 binoculars from vehicle and foot. To minimize the effect of wind, we conducted surveys from sunrise to 1200 h and 1600 h to sunset (Helmers 1992, Stone 1994). We surveyed 8 points from fixed locations along the shore of the Cumberland Pool, allocated proportionally in shoreline habitats of the Cumberland Pool. The combination of those proportions represent the sampled proportions of all macrohabitats. The order of surveying the 8 points was chosen randomly for every survey. We recorded total number of shorebirds along the delineated distance and numbers of shorebirds using water, wet land, or dry land. We used water, wet land, and dry land as parameters to delineate microhabitat. Other studies have used soil moisture in their delineation of habitats (Burger et al. 1977, Colwell and Oring 1988). When possible, shorebirds were identified to species; otherwise, they were categorized by groups (e.g., small sandpipers, medium sandpipers, yellowlegs, etc.) described by Helmers (1992). We did not conduct surveys during extremely windy and stormy conditions. Surveys were conducted at least biweekly (Rundle and Fredrickson 1981, Ryan et al. 1984, Hands et al. 1991) during the following time periods: 16 March 1996-19 May 1996 (spring 1996), 20 July 1996-14 September 1996 (autumn 1996), 14 March 1997-13 May 1997 (spring 1997), and 24 July 1997-18 October 1997 (autumn 1997).

Data analysis.—We used chi-square analyses (Cochran 1954) to test the null hypothesis that shorebirds used macro- and microhabitats in proportion to their availabilities and a Bonferroni Z-statistic (Neu et al. 1974, Leslie and Stancill 1990) to evaluate macro- and microhabitat selection. Selection was analyzed for each macrohabitat within each season. We indexed availability of each macrohabitat as the linear distance of shoreline. Our approach to the statistical evaluation of microhabitat selection was hierarchical (Leslie and Stancill 1990). Shorebird selection of microhabitats was evaluated in only selected macrohabitats. We reasoned that if macrohabitats were avoided, microhabitats within these areas were similarly avoided. Statistical significance was set at $\alpha < 0.05$.

We recorded water level for the Cumberland Pool during each survey using water markers, maintained by the refuge. We used Spearman rank correlation (Zar 1984) to test if abundance of shorebirds was correlated with water level of the Cumberland Pool.

RESULTS

We counted 2,725 shorebirds during all sampling seasons in 1996-1997. Fifteen species of shorebirds were identified (Table 2). According to Helmers et al. (1992) groupings, we identified 8 groups of shorebirds. The dominant shorebird group was the small sandpipers, which comprised 85.9% of the total community.

Shorebirds were found only within the disturbed, deciduous, and mudflat macrohabitats. The majority of shorebirds (99.2%) were observed in the mudflat macrohabitat (Table 3). In every season, except fall 1997, shorebirds selected the mudflat macrohabitat ($\underline{P} < 0.05$). No shorebirds were observed in autumn 1997 (Table 3).

Because shorebirds selected only the mudflat macrohabitat, we analyzed it for microhabitat use. Two groups, plover and turnstone, were excluded from the microhabitat analysis because they made up <1% of the shorebirds surveyed. Including those shorebird groups would not be valid because ≤20% of the expected frequencies should be <5.0 in a Chi-square analysis (Cochran 1954). Small sandpipers were the only group to select for wetland. All other groups selected for water. No groups selected for dry land (Table 4).

The dynamic nature of the Cumberland Pool affected the abundance of shorebirds (Fig. 1). There was a negative correlation between pool level and number of shorebirds per survey ($r_s = -0.36$, $n = 58$, $P = 0.0048$). As water level of the pool increased, abundance of shorebirds decreased. Lake levels were different between years. Water levels in 1996 were low with an increase in autumn. Water levels in 1997 were high with a decrease in autumn.

DISCUSSION

Shorebirds selected mudflats over habitats with snags, deciduous trees, and human disturbance (Table 3). Taylor et al. (1993) reported that the majority of shorebirds at a reservoir in Idaho also used mudflat habitat. Shorebirds tend to concentrate on mudflats at inland sites during migration (Taylor et al. 1993). Skagen and Knopf (1994b) also reported the tendency of shorebirds to occupy wet mud-shallow water habitats at Quivera NWR, Kansas. Other studies (Rundle and Frederickson 1981, Taylor and Trost 1992) documented shorebird use of mudflats at inland sites.

Others have studied shorebird habitat use of microhabitats using soil moisture to delineate critical habitats (Burger et al. 1977, Colwell and Oring 1988). Colwell and Oring (1988) reported that dowitchers (Limnodromus spp.), godwits (Limosa spp.), phalaropes (Phalaropes spp.), and yellowlegs (Tringa spp.) used water microhabitat while small sandpipers used mudflats and avocets used upland habitats in south-central Saskatchewan. Our results support those findings except for the avocet group. We found that avocets selected water microhabitat (Table 4), but not upland or dry habitat. No shorebirds used the dry-land habitat at Tishomingo NWR (Table 4). The difference in habitat use of avocets between these 2 sites may be due to breeding and nonbreeding behavior. Tishomingo NWR is on the border of the breeding range of the avocet group while south-central Saskatchewan is well within their breeding range (American Ornithologists' Union 1983).

Like other studies (Taylor et al. 1993, Skagen and Knopf 1994b), we found a relationship between water level and shorebird use. Unlike those studies, we evaluated a body of water that can not be manipulated. Managers at Tishomingo NWR cannot control water levels to manage for shorebirds. Factors that influence water level will play a larger role at an unmanaged site like Tishomingo NWR compared with Quivera NWR. Factors that affect water level include precipitation, surface inflow and outflow, groundwater, and evapotranspiration (Mitsch and Gosselink 1993). As is typical in the Great Plains, water input to Tishomingo NWR is especially variable (Skagen and Knopf 1994a). Our results show that an increase in water level is associated with a reduction of shorebirds (Fig. 1). The water level of the Cumberland Pool reached 197 m above msl in 1990, probably leading to few shorebirds at Tishomingo NWR. Concurrently, Skagen and Knopf (1993) reported that refuges in North and South Dakota experienced a greater number of shorebirds in 1990. The reduction in the number of shorebirds with an increase in water level suggests that shorebirds use Tishomingo NWR opportunistically (Skagen and Knopf 1994b).

Shorebirds in the Great Plains have been characterized as using habitats opportunistically (Skagen and Knopf 1993). We observed this at a very fine scale. We removed 2 samples of 60 because we considered them outliers. Those 2 samples occurred in the spring of 1997 when water covered the mudflats. Shorebirds in those 2 samples concentrated within an agricultural field located upland from a mudflat. Water had moved into the tilled field and created shallow pools. Hands et al. (1991) reported that some agricultural units supported substantial numbers of shorebirds in spring. In times of high water levels, Tishomingo NWR may play a role in migration due to yearly agricultural practices.

The majority of shorebirds observed at Tishomingo NWR were small sandpipers. These smaller shorebirds have higher mass-specific metabolic rates than larger birds (Calder 1984) and can accumulate less body fat (Skagen and Knopf 1993). We hypothesize that the inability to accumulate substantial body fat results in the "hopping" migration strategy described by Piersma (1987). Skagen and Knopf (1994a) suggested that most semipalmated (Calidris pusilla) and white-rumped (C. fuscicollis) sandpipers that left Quivera NWR were not able to reach their breeding ground in one long migration or jump. They required stopover sites between the central Great Plains and their breeding grounds in northern Canada (American Ornithologists' Union 1983), suggesting the hopping migration strategy.

Tishomingo NWR may be an important stopover site for shorebirds that require many stops along their migration route. It also serves as a protected area in a time of decreasing wetlands (Howe 1987). Although Tishomingo NWR is not as large as other stopover sites identified by Skagen and Knopf (1993), such as Cheyenne Bottoms Wildlife Management Area in central Kansas, it together with many other comparably sized wetlands, likely play an integral role in the migration of small sandpipers in the Great Plains.

ACKNOWLEDGEMENTS

We thank the Trust for Public Land, Tishomingo National Wildlife Refuge, and the Oklahoma Cooperative Fish and Wildlife Research Unit (Oklahoma Department of Wildlife Conservation, Oklahoma State University, U.S. Geological Survey Biological Resource Division, and Wildlife Management Institute, cooperating) for financial and logistical support. We acknowledge A. Craft, S. Larrabee, and D. Underwood for their assistance in the field.

LITERATURE CITED

AMERICAN ORNITHOLOGISTS' UNION. 1983. Check-list of North American birds, 6th edition. Allen Press, Lawrence, Kansas, 877pp.

ASHKENAZIE, S. AND U. N. SAFRIEL. 1979. Time-energy budget of the semipalmated sandpiper _Calidris pusilla_ at Barrow, Alaska. Ecology 60:783-799.

BURGER, J., M. A. HOWE, D. C. HAHN, AND J. CHASE. 1977. Effects of tide cycles on habitat selection and habitat partitioning by migrating shorebirds. Auk 94:743-758.

CALDER, W. A., III. 1984. Size, function, and life history. Harvard University Press, Cambridge, Massachusetts.

COCHRAN, W. G. 1954. Some methods for strengthening the common X^2 tests. Biometrics 10:417-451.

COLWELL, M. A., AND L. W. ORING. 1988. Habitat use by breeding and migratory shorebirds in south-central Saskatchewan. Wilson Bull. 100:554-566.

DUCK, L. G., AND J. B. FLETCHER. 1943. A game type map of Oklahoma. Oklahoma Game and Fish Dept., Oklahoma City.

GREAT PLAINS FLORA ASSOCIATION. 1986. Flora of the Great Plains. University Press of Kansas. Lawrence, Kansas, 1392 pp.

HANDS, H. M., M. R. RYAN, AND J. W. SMITH. 1991. Migrant shorebird use of marsh, moist-soil, and flooded agricultural habitats. Wildl. Soc. Bull. 19:457-464.

HELMERS, D. L. 1992. Shorebird management manual. Western Hemisphere Shorebird Reserve Network, Manomet, Massachusetts. 58pp.

HILDEN, O. 1979. Territoriality and site tenacity of Temminck's Stint (Calidris temminckii). Ornis Fennica 56:56-74.

HOWE, M. A. 1987. Wetlands and waterbird conservation. Am. Birds 41:204-209.

LESLIE, D. M., JR., AND W. J. STANCILL. 1990. Importance of an old multiple-use reservior to migrating and wintering dabbling ducks. Prairie Naturalist 22:231-244.

MITSCH, W. J., AND J. G. GOSSELINK. 1993. Wetlands, 2nd edition. Van Nostrand Reinhold, New York. 722pp.

MYERS, J. P. 1983. Conservation of migrating shorebirds: staging areas, geographic bottlenecks, and regional movements. Am. Birds 37:23-25.

_____, R. I. G. MORRISON, P. Z. ANTAS, B. A. HARRINGTON, T. E. LOVEJOY, M. SALLABERRY, S. E. SENNER, AND A. TARAK. 1987. Conservation strategy for migratory species. Am. Sci. 75:19-26.

NEU, C. W., C. R. BYERS, AND J. M. PEEK. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.

PFISTER, C., B. A. HARRINGTON, AND M. LAVINE. 1992. The impact of human disturbance on shorebirds at a migration staging area. Biol. Conserv. 60:115-126.

PIERSMA, T. 1987. Hop, skip, or jump? Constraints on migration of arctic waders by feeding, fattening, and flight speed. Limosa 60:185-194.

RUNDLE, W. D., AND L. H. FREDERICKSON. 1981. Managing seasonally flooded impoundments for migrant rails and shorebirds. Wildl. Soc. Bull. 9:80-87.

RYAN, M. R., R. B. RENKEN, AND J. J. DINSMORE. 1984. Marbled godwit habitat selection in the northern prairie region. J. Wildl. Manage. 48:1206-1218.

SKAGEN, S. K., AND F. L. KNOPF. 1993. Toward conservation of midcontinental shorebird migrations. Conserv. Biol. 7(3):533-541.

_____, AND _____. 1994a. Residency patterns of migrating sandpipers at a midcontinental stopover. The Condor 96:949-958.

_____, AND _____. 1994b. Migrating shorebirds and habitat dynamics at a prairie wetland complex. Wilson Bull. 106:91-105.

STONE, K. L. 1994. Shorebird habitat use and response to burned marshes during spring migration in South-Central Kansas. M.S. Thesis, Oklahoma State University, Stillwater. 92pp.

TAYLOR, D. M., AND C. H. TROST. 1992. Use of lakes and reservoirs by migrating shorebirds in Idaho. Great Basin Nat. 52:179-184.

_____, _____, AND B. JAMISON. 1993. Migrant shorebird habitat use and the influence of water level at American Falls Reservoir, Idaho. Northwest Nat. 74:33-40.

ZAR, J. H. 1984. Biostatistical Analysis. 2nd ed. Prentice-Hall, Englewood Cliffs, NJ 718 pp.

Table 1-Habitat type, distance, and percent habitat for actual and surveyed shoreline of the Cumberland Pool at Tishomingo National Wildlife Refuge, Oklahoma.

	Actual Shoreline		Surveyed Shoreline	
Habitat	Distance (m)	%	Distance (m)	%
Disturbed	2,208	8	245	6
Deciduous	6,389	23	1,040	26
Snags	8,113	29	738	20
Mudflat	11,089	40	1,898	48

Table 2-Shorebird groups and species (Helmers et al. 1992) sampled at Tishomingo National Wildlife Refuge in 1996-1997.

Shorebird Group	Common name	Scientific Name
Plover	Lesser Golden Plover	Pluvialis squatarola
Small Sandpiper	Western Sandpiper	Calidris mauri
	Least Sandpiper	Calidris minutilla
	White-rumped Sandpiper	Calidris fuscicollis
	Baird's Sandpiper	Calidris bairdii
Medium Sandpiper	Short-billed Dowitcher	Limondromus griseus
	Long-billed Dowitcher	Limondromus scolopaceus
Godwit	Marbled Godwit	Limosa fedoa
Yellowlegs	Greater Yellowlegs	Tringa melanocephala
	Lesser Yellowlegs	Tringa flavipes
	Solitary Sandpiper	Tringa solitaria

Table 2. Continued.

Shorebird Group	Common name	Scientific Name
	Willet	Catoptrophorus semipalmatus
Turnstone	Spotted Sandpiper	Actites macularia
Avocet/Stilt	American Avocet	Recurvirostra americana
Phalarope	Wilson's Phalarope	Phalaropus tricolor

Table 3-Number of shorebirds observed seasonally in macrohabitats of Tishomingo National Wildlife Refuge, Oklahoma, spring 1996-autumn 1997.

		Observed Use[1]			
Season	Surveys	Disturbed	Deciduous	Snags	Mudflat
Spring 1996	20	3-	0-	0-	1,303+
Fall 1996	17	6-	1-	0-	455+
Spring 1997	8	10-	0-	0-	947+
Fall 1997	15	0	0	0	0

[1]Significant selection (+) or avoidance (-) of habitats relative to availability from simultaneous 95% Bonferroni confidence intervals (Nue et al. 1974).

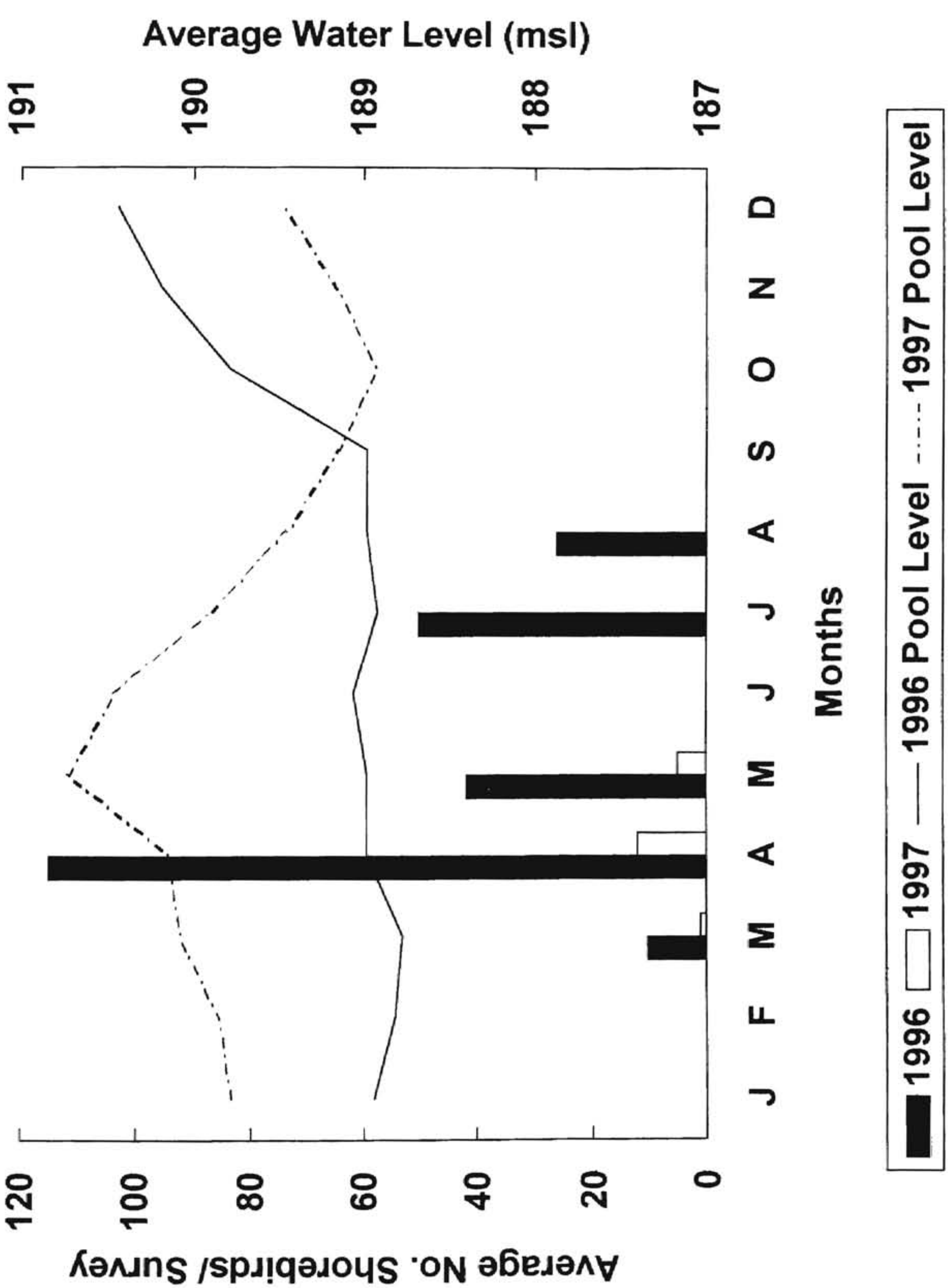
Table 4-Number of shorebirds observed in microhabitats of the mudflat macrohabitat at Tishomingo National Wildlife Refuge, Oklahoma, spring 1996-autumn 1997.

		Microhabitat[1]		
Group[2]	n	Water	Wetland	Dryland
Avocets	42	42+	0-	0-
Dowitchers	99	99+	0-	0-
Godwits	76	76+	0-	0-
Small Sandpipers	2,320	766	1,554+	0-
Phalaropes	72	72+	0-	0-
Yellowlegs	93	87+	6-	0-

[1]Significant selection (+) or avoidance (-) of habitats relative to availability from simultaneous 95% Bonferroni confidence intervals (Nue. et al. 1974).

[2]Shorebird groups defined by Helmers et al. (1992).

Fig. 1-Shorebird abundance (average number of shorebirds/survey) and average water level (feet above mean sea level; msl) of Cumberland Pool, Tishomingo National Wildlife Refuge, Oklahoma, 1996 and 1997.



Average No. Shorebirds/ Survey
Average Water Level (msl)
Months
J F M A M J J A S O N D
0 20 40 60 80 100 120
187 188 189 190 191
1996
1997
1996 Pool Level
1997 Pool Level

APPENDICES

Appendix A. Habitats and methods for all terrestrial vertebrates identified at Tishomingo National Wildlife Refuge, Oklahoma.

Common Name	Scientific Name	Habitat	Method
Avifauna (107 total)			
American Avocet	Recurvirostra americana	Barren	Shorebird Survey
American Coot	Fulica americana	Wetland	Point Survey
		Wetland	Accidental
American Crow	Corvus brachyrhynchos	Wetland	Point Survey
		Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Oak/Hickory Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
American Goldfinch	Carduelis tristis	Wetland	Point Survey
American Kestrel	Falco sparverius	Grassland/Shrub Combined	Point Survey
		Wetland	Point Survey

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
American Robin	*Turdus migratorius*	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Oak/Hickory Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Bald Eagle	*Haliaeetus leucocephalus*	Wetland	Point Survey
Barn Swallow	*Hirundo rustica*	Grassland/Shrub Combined	Point Survey
Barred Owl	*Strix varia*	Grassland/Shrub Combined	Point Survey
		Oak Woodland	Point Survey
Belted Kingfisher	*Ceryle alcyon*	Wetland	Point Survey
		River	Accidental
Bewick's Wren	*Thryomanes bewickii*	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Oak/Hickory Forest	Point Survey

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
		Wetland	Point Survey
Black Vulture	Coragyps atratus	Wetland	Point Survey
Blue Grosbeak	Guiraca caerulea	Oak Woodland	Point Survey
Blue Jay	Cyanocitta cristata	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Oak/Hickory Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Blue-Gray Gnatcatcher	Polioptila caerulea	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Oak/Hickory Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Brown Creeper	Certhia americana	Willow/Cottonwood Forest	Point Survey

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
Brown Thrasher	Toxostoma rufum	Oak/Hickory Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Brown-Headed Cowbird	Molothrus ater	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Oak/Hickory Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Canada Goose	Branta canadensis	Grassland/Shrub Combined	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Carolina Chickadee	Parus carolinensis	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
		Oak/Hickory Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Carolina Wren	*Thryothorus ludovicianus*	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Oak/Hickory Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Cattle Egret	*Bubulcus ibis*	Grassland/Shrub Combined	Point Survey
		Wetland	Point Survey
Chimney Swift	*Chaetura pelagica*	Grassland/Shrub Combined	Point Survey
Chuck-Will's-Widow	*Caprimulgus carolinensis*	Oak/Hickory Forest	Accidental
Common Grackle	*Quiscalus quiscula*	Wetland	Point Survey
Cooper's Hawk	*Accipiter cooprii*	Grassland/Shrub Combined	Point Survey

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
		Wetland	Point Survey
Dark-Eyed Junco	Junco hyemalis	Oak Woodland	Point Survey
Dickcissel	Spiza americana	Grassland/Shrub Combined	Point Survey
		Oak Woodland	Point Survey
Double-Crested Cormorant	Phalacrocorax auritus	Oak Woodland	Point Survey
Downy Woodpecker	Picoides pubescens	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Oak/Hickory Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Eastern Bluebird	Sialia sialis	Oak/Hickory Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Eastern Kingbird	Tyrannus tyrannus	Oak/Hickory Forest	Point Survey

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
		Wetland	Point Survey
Eastern Phoebe	Sayornis phoebe	Grassland/Shrub Combined	Point Survey
		Oak Woodland	Point Survey
Eastern Screech-Owl	Otus asio	Oak/Hickory Forest	Point Survey
European Starling	Sturnus vulgaris	Urban, Vegetated	Accidental
Field Sparrow	Spizella pusilla	Grassland/Shrub Combined	Point Survey
		Oak/Hickory Forest	Point Survey
		Oak Woodland	Point Survey
Fish Crow	Corvus ossifragus	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Oak/Hickory Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Fox Sparrow	Passerella iliaca	Oak Woodland	Point Survey

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
Franklin's Gull	Larus pipixcan	Lake	Accidental
Gray Catbird	Dumetella carolinensis	Willow/Cottonwood Forest	Point Survey
		Oak Woodland	Point Survey
Great Blue Heron	Ardea herodias	Willow/Cottonwood Forest	Point Survey
		Oak/Hickory Forest	Point Survey
		Oak Woodland	Point Survey
Great Crested Flycatcher	Myiarchus crinitus	Wetland	Point Survey
Great Egret	Casmerodius albus	Wetland	Point Survey
Great Horned Owl	Bubo virginianus	Urban, Vegetated	Accidental
Greater Roadrunner	Geococcyx californianus	Urban, Vegetated	Accidental
Greater White-Fronted Goose	Anser albifrons	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
Greater Yellowlegs	*Tringa melanleuca*	Barren	
Herring Gull	*Larus argentatus*	Lake	Point Survey
		Lake	Point Survey
House sparrow	*Passer domesticus*	Urban, vegetated	Accidental
Indigo Bunting	*Passerina cyanea*	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Oak/Hickory Forest	Point Survey
		Oak Woodland	Point Survey
Killdeer	*Charadrius vociferus*	Grassland/Shrub Combined	Point Survey
Least Sandpiper	*Calidris minutilla*	Barren	Shorebird Survey
Lesser Scaup	*Aythya affinis*	Wetland	Point Survey
Lesser Yellowlegs	*Tringa flavipes*	Barren	Shorebird Survey
Loggerhead Shrike	*Lanius ludovicianus*	Grassland/Shrub Combined	Point Survey
		Oak Woodland	Point Survey
Mallard	*Anas platyrhynchos*	Wetland	Point Survey

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
Marbled Godwit	Limosa fedoa	Barren	Shorebird Survey
Mississippi Kite	Ictinia mississippiensis	Willow/Cottonwood Forest	Accidental
Mourning Dove	Zenaida macroura	Grassland/Shrub Combined	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Northern Bobwhite	Colinus virginianus	Grassland/Shrub Combined	Point Survey
		Oak Woodland	Point Survey
		Grassland (with trees)	Accidental
Northern Cardinal	Cardinalis cardinalis	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Oak/Hickory Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Northern Flicker	Colaptes auratus	Grassland/Shrub Combined	Point Survey

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
		Oak/Hickory Forest	Point Survey
Northern Harrier	Circus cyaneus	Grassland (with shrub)	Accidental
Northern Mockingbird	Mimus polyglottos	Oak Woodland	Point Survey
		Grassland/Shrub Combined	Point Survey
		Wetland	Point Survey
		Urban, Vegetated	Accidental
Northern Shoveler	Anas clypeata	Wetland	Point Survey
		Lake	Accidental
Opossum	Didelphis virginiana	Urban, Vegetated	Accidental
Orange-Crowned Warbler	Vermivora celata	Oak Woodland	Point Survey
Painted Bunting	Passerina ciris	Grassland/Shrub Combined	Point Survey
		Oak Woodland	Point Survey
Pied-Billed Grebe	Podilymbus podiceps	Wetland	Point Survey
Pileated Woodpecker	Dryocopus pileatus	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
		Oak/Hickory Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Prothonotary Warbler	*Protonotaria citrea*	Willow/Cottonwood Forest	Point Survey
		Wetland	Point Survey
Purple Martin	*Progne subis*	Grassland/Shrub Combined	Point Survey
		Wetland	Point Survey
Red-Bellied Woodpecker	*Melanerpes carolinus*	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Oak/Hickory Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Red-Headed Woodpecker	*Melanerpes erthrocephalus*	Grassland/Shrub Combined	Point Survey

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
		Wetland	Point Survey
Red-Shouldered Hawk	Buteo lineatus	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Oak/Hickory Forest	Point Survey
		Oak Woodland	Point Survey
Red-Tailed Hawk	Buteo jamaicensis	Grassland/Shrub Combined	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Red-Winged Blackbird	Agelaius phoeniceus	Grassland/Shrub Combined	Point Survey
		Wetland	Point Survey
Ring-billed Gull	Larus delawarrensis	Lake	Accidental
Rose-Breasted Grosbeak	Pheucticus ludovicianus	Wetland	Point Survey
Ross' Goose	Chen rossii	Grassland/Shrub Combined	Point Survey
Ruby-Crowned Kinglet	Regulus calendula	Willow/Cottonwood Forest	Point Survey

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
		Wetland	Point Survey
		Oak Woodland	Point Survey
Ruby-Throated Hummingbird	Archilochus colubris	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Oak Woodland	Point Survey
Scissor-Tailed Flycatcher	Tyrannus forficatus	Grassland/Shrub Combined	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Snow Goose	Chen caerulescens	Grassland/Shrub Combined	Point Survey
		Oak Woodland	Point Survey
Snowy Egret	Egretta thula	Wetland	Point Survey
Solitary Sandpiper	Tringa solitaria	Barren	Shorebird Survey
		Urban, Vegetated	Shorebird Survey
Song Sparrow	Melospiza melodia	Grassland/Shrub Combined	Point Survey

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
		Oak Woodland	Point Survey
Spotted Sandpiper	*Actitis macularia*	Urban, Vegetated	Shorebird Survey
		Barren	Shorebird Survey
Swainson's Warbler	*Limnothlypis swainsonii*	Willow/Cottonwood Forest	Point Survey
Tufted Titmouse	*Parus bicolor*	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Oak/Hickory Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Turkey Vulture	*Cathartes aura*	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Upland Sandpiper	*Bartramia longicauda*		

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
Western Sandpiper	Calidrus minutilla	Barren	Shorebird Survey
Whip-Poor-Will	Caprimulgus vociferus	Oak/Hickory Forest	Accidental
White-Breated Nuthatch	Sitta carolinensis	Willow/Cottonwood Forest	Point Survey
		Oak/Hickory Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
White-Throated Sparrow	Zonotrichia albicollis	Willow/Cottonwood Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Wild Turkey	Meleagris gallopavo	Grassland/Shrub Combined	Point Survey
Willet	Catoptrophorus semipalmatus	Barren	Shorebird Survey
Willow Flycatcher	Empidonax traillii	Oak/Hickory Forest	Point Survey
Wilson's Phalarope	Phalaropus tricolor	Barren	Shorebird Survey
Winter Wren	Troglodytes troglodytes	Willow/Cottonwood Forest	Point Survey

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
Wood Duck	*Aix sponsa*	Willow/Cottonwood Forest	Point Survey
		Wetland	Point Survey
Yellow Warbler	*Dendroica petechia*	Willow/Cottonwood Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Yellow-Billed Cuckoo	*Coccyzus americanus*	Grassland/Shrub Combined	Point Survey
		Willow/Cottonwood Forest	Point Survey
		Oak/Hickory Forest	Point Survey
		Wetland	Point Survey
		Oak Woodland	Point Survey
Yellow-Rumped Warbler	*Dendroica coronata*	Grassland/Shrub Combined	Point Survey
		Oak/Hickory Forest	Point Survey
		Wetland	Point Survey

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
		Oak Woodland	Point Survey
Yellow-Throated Warbler	Dendroica dominica	Wetland	Point Survey
Herpetofauna (31 total)			
Black Rat Snake	Elaphe obsoleta	Upland Shrub	Search Station
Blanchard's Cricket Frog	Acris crepitans	Lake	Unconstrained Search
		Pond	Accidental
		Pond	Unconstrained Search
		River	Accidental
		River	Unconstrained Search
		Oak/Hickory Forest	Unconstrained Search
		Willow/Cottonwood Forest	Unconstrained Search
		Wetland	Search Station

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
Broadhead Skink	Eumeces laticeps	Oak/Hickory Forest	Unconstrained Search
Brown Snake	Storeria dekayi	Willow/Cottonwood Forest	Drift Fence
Common Garter Snake	Thamnophis sirtalis	Agriculture	Accidental
Common Snapping Turtle	Chelydra serpentina	Lake	Accidental
Copperhead	Agkistrodon contortrix	Oak/Hickory Forest	Search Station
Diamonback Water Snake	Nerodia rhombifer	Pond	Accidental
Dwarf American Toad	Bufo americanus	Urban, Vegetated	Unconstrained Search
		Field/Shrub	Accidental
Eastern Hognose Snake	Heterodon platirhinos	Field/Shrub	Accidental
Eastern Narrowmouth Toad	Gastrophryne carolinensis	Pond	Accidental
Fence Lizard	Sceloporus undulatus	Urban, Vegetated	Unconstrained Search
		Oak/Hickory Forest	Search Station
		Willow/Cottonwood Forest	Unconstrained Search
Five-Lined Skink	Eumeces fasciatus	Oak/Hickory Forest	Search Station
Flathead Snake	Tantilla gracilis	Oak/Hickory Forest	Search Station

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
Gray Treefrog	Hyla versicolor	Oak/Hickory Forest	Accidental
		Oak/Hickory Forest	Unconstrained Search
Ground Skink	Scincella lateralis	Oak/Hickory Forest	Accidental
		Oak/Hickory Forest	Unconstrained Search
		Oak/Hickory Forest	Search Station
Hurter's Spadefoot	Scaphiopus bombifrons	Grassland (with Trees)	Drift Fence
Northern Redbelly Snake	Storeria occipitomaculata	Oak/Hickory Forest	Accidental
Northern Water Snake	Nerodia sipedon	Pond	Accidental
Ornate Box Turtle	Terrapene ornata	Oak/Hickory Forest	Accidental
		Oak/Hickory Forest	Unconstrained Search
Ouachita Map Turtle	Graptemys pseudogeographica	Lake	Unconstrained Search
		Oak/Hickory Forest	Unconstrained Search
Racerunner	Cnemidophorus sexlineatus	Urban, Vegetated	Unconstrained Search
		Oak/Hickory Forest	Unconstrained Search

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
		Field	Accidental
		Field/Shrub	Accidental
Red-Eared Turtle	*Trachemys scripta*	Agriculture	Accidental
		Lake	Accidental
		Pond	Accidental
		Oak/Hickory Forest	Accidental
		Oak/Hickory Forest	Unconstrained Search
Rough Green Snake	*Opheodrys aestivus*	Pond	Unconstrained Search
		Oak/Hickory Forest	Unconstrained Search
Southern Leopard Frog	*Rana utricularia*	Pond	Unconstrained Search
		Oak/Hickory Forest	Accidental
		Willow/Cottonwood Forest	Accidental
		Willow/Cottonwood Forest	Unconstrained Search

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
		Willow/Cottonwood Forest	Search Station
Spiny Softshell	*Apalone spinifera*	Lake	Unconstrained Search
Three-Toed Box Turtle	*Terrapene carolina*	Urban, Vegetated	Accidental
		Urban, Vegetated	Unconstrained Search
		Oak/Hickory Forest	Accidental
		Oak/Hickory Forest	Unconstrained Search
		Oak/Hickory Forest	Search Station
Timber Rattlesnake	*Crotalus horridus*	Oak/Hickory Forest	Accidental
		Oak/Hickory Forest	Unconstrained Search
		Grassland (With Trees)	Unconstrained Search
Western Cottonmouth	*Agkistrodon piscivorous*	Pond	Unconstrained Search
		Grassland (With Trees	Search Station
Western Ribbon Snake	*Thamnophis proximus*	Wetland	Search Station
		Woodland	Unconstrained Search

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
Woodhouse's Toad	*Bufo woodhousii*	Willow/Cottonwood Forest	Search Station
Mammals (18 total)			
Armadillo	*Dasypus novemcinctus*	Agriculture	Scent Station
		Oak/Hickory Forest	Scent Station
Beaver	*Castor canadensis*	Pond	Accidental
Bobcat	*Lynx rufus*	Agriculture	Scent Station
		Grassland (With Shrub)	Scent Station
		Willow/Cottonwood Forest	Scent Station
		Oak/Hickory Forest	Scent Station
Coyote	*Canis latrans*	Agriculture	Scent Station
		Grassland (With Shrub)	Scent Station
		Oak/Hickory Forest	Scent Station

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
Deer Mouse	*Peromyscus maniculatus*	Agriculture	Snap Trap
		Grassland (With Shrub)	Snap Trap
		Willow/Cottonwood Forest	Snap Trap
		Upland Shrub	Snap Trap
		Oak/Hickory Forest	Snap Trap
		Wetland	Snap Trap
Eastern Woodrat	*Neotoma floridana*	Agriculture	Snap Trap
		Willow/Cottonwood Forest	Snap Trap
		Oak/Hickory Forest	Snap Trap
Eastern Cottontail	*Sylvilagus floridanus*	Urban, vegetated	Accidental
Elliot's Short-Tailed Shrew	*Blarina hylophaga*	Willow/Cottonwood Forest	Snap Trap
		Upland Shrub	Snap Trap
Feral Hog	*Sus scrofa*	Willow/Cottonwood Forest	Scent Station
Fox Squirrel	*Sciurus niger*	Urban, Vegetated	Accidental

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
		Oak/Hickory Forest	Accidental
Fulvous Harvest Mouse	Reithrodontomys fulvescens	Grassland (With Shrub)	Snap Trap
		Wetland	Snap Trap
Hispid Cotton Rat	Sigmodon hispidus	Grassland (With Shrub)	Snap Trap
		Willow/Cottonwood Forest	Snap Trap
		Upland Shrub	Snap Trap
		Wetland	Snap Trap
House Cat	Felis domesticus	Grassland (With Shrub)	Scent Station
		Oak/Hickory Forest	Scent Station
Opossum	Didelphis virginiana	Agriculture	Scent Station
		Willow/Cottonwood Forest	Scent Station
		Urban, Vegetated	Accidental
		Oak/Hickory Forest	Scent Station
Raccoon	Procyon lotor	Agriculture	Scent Station

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
		Grassland (With Shrub)	Scent Station
		Urban, Vegetated	Accidental
		Willow/Cottonwood Forest	Scent Station
		Oak/Hickory Forest	Scent Station
Striped Skunk	*Mephitis mephitis*	Agriculture	Scent Station
		Urban, Vegetated	Accidental
White-Footed Mouse	*Peromyscus leucopus*	Agriculture	Snap Trap
		Grassland (With Shrub)	Snap Trap
		Willow/Cottonwood Forest	Snap Trap
		Upland Shrub	Snap Trap
		Oak/Hickory Forest	Snap Trap
		Wetland	Snap Trap
White-Tailed Deer	*Odocoileus virginianus*	Agriculture	Scent Station

Appendix A. Continued.

Common Name	Scientific Name	Habitat	Method
		Grassland (With Shrub)	Scent Station
		Willow/Cottonwood Forest	Scent Station
		Oak/Hickory Forest	Scent Station

Appendix B. Relative abundance (total no. birds/total no. of point counts) of avifauna sampled at Tishomingo National Wildlife Refuge, Oklahoma, during fall 1996 and winter, spring, and summer 1997.

			Season			
Species	Scientific Name	Habitat Type	Spr	Sum	Fall	Win
American Coot	Fulica americana	Wetland			1.00	
American Crow	Corvus brachyrhynchos	Field/Shrub				0.67
		Willow/Cottonwood Forest	0.50		0.50	
		Oak/Hickory Forest	0.33			0.17
		Wetland		0.17	0.83	0.33
		Oak Woodland	0.33			0.33
American Goldfinch	Carduelis tristis	Wetland				0.17
American Robin	Turdus migratorius	Field/Shrub	0.17			
		Willow/Cottonwood Forest		0.50		
		Oak/Hickory Forest		0.33		
		Oak Woodland			0.33	

Appendix B. Continued

			Season			
Species	Scientific Name	Habitat Type	Spr	Sum	Fall	Win
Bald Eagle	Haliaeetus leucocephalus	Wetland				0.5
Bewick's Wren	Thryomanes bewickii	Field/Shrub			0.17	
		Willow/Cottonwood Forest			0.17	0.17
		Oak/Hickory Forest			0.17	
		Wetland				0.33
Blue Grosbeak	Guiraca caerulea	Oak Woodland		0.17		
Blue Jay	Cyanocitta cristata	Field/Shrub			1.33	
		Oak/Hickory Forest			1.50	0.83
		Wetland			1.33	0.33
		Oak Woodland			0.50	0.50
Blue-Gray Gnatcatcher	Polioptila caerulea	Field/Shrub	0.33	0.17		
		Willow/Cottonwood Forest	0.50			
		Oak/Hickory Forest	0.83	0.17		

Appendix B. Continued

Species	Scientific Name	Habitat Type	Season Spr	Sum	Fall	Win
		Wetland	1.00			
		Oak Woodland	0.67	0.33		
Brown Creeper	Certhia americana	Willow/Cottonwood Forest				0.17
Brown Thrasher	Toxostoma rufum	Oak/Hickory Forest			0.17	
		Wetland			0.33	
		Oak Woodland		0.17	0.17	0.17
Brown-Headed Cowbird	Molothrus ater	Field/Shrub	0.50			
		Wetland	0.50			
		Oak Woodland	0.33			
Canada Goose	Branta canadensis	Wetland				16.67
Carolina Chickadee	Parus carolinensis	Field/Shrub		0.17	0.50	0.50
		Willow/Cottonwood Forest			0.50	0.67
		Oak/Hickory Forest	0.33	0.33	1.17	1.00

Appendix B. Continued

			Season			
Species	Scientific Name	Habitat Type	Spr	Sum	Fall	Win
		Wetland	0.67	0.17	0.17	1.83
		Oak Woodland	0.33		0.83	1.00
Carolina Wren	*Thryothorus ludovicianus*	Field/Shrub	0.17	0.33	0.17	0.17
		Willow/Cottonwood Forest	0.67	0.17	0.50	0.17
		Oak/Hickory Forest	0.17	0.33	0.17	0.67
		Wetland	0.33	0.17	0.17	1.00
		Oak Woodland	0.17	0.33	0.17	0.50
Dark-Eyed Junco	*Junco hyemalis*	Oak Woodland			0.33	
Dickcissel	*Spiza americana*	Field/Shrub	0.83	1.17		
		Oak Woodland	0.17	0.17		
Downy Woodpecker	*Picoides pubescens*	Willow/Cottonwood Forest			0.17	1.00
		Oak/Hickory Forest				0.33
		Wetland			0.17	

Appendix B. Continued

			Season			
Species	Scientific Name	Habitat Type	Spr	Sum	Fall	Win
		Oak Woodland			0.50	0.17
Eastern Bluebird	<u>Sialia sialis</u>	Wetland			0.33	
		Oak Woodland			3.17	0.50
Eastern Kingbird	<u>Tyrannus tyrannus</u>	Oak/Hickory Forest	0.17			
		Wetland	0.33			
Eastern Phoebe	<u>Sayornis phoebe</u>	Field/Shrub			0.33	
		Oak Woodland	0.33		0.33	
Field Sparrow	<u>Spizella pusilla</u>	Field/Shrub	0.67	0.17		0.17
		Oak/Hickory Forest		0.17		
		Oak Woodland	0.67	0.17		
Fish Crow	<u>Corvus ossifragus</u>	Willow/Cottonwood Forest	0.67			
		Oak Woodland		0.17		
Fox Sparrow	<u>Passerella iliaca</u>	Oak Woodland				0.17

Appendix B. Continued

Species	Scientific Name	Habitat Type	Season Spr	Sum	Fall	Win
Gray Catbird	Dumetella carolinensis	Willow/Cottonwood Forest	0.33			
		Oak Woodland	0.17			
Great Blue Heron	Ardea herodias	Field/Shrub		0.17		
		Willow/Cottonwood Forest	0.17			
Great Crested Flycatcher	Myiarchus crinitus	Wetland	0.17			
Greater White-Fronted Goose	Anser albifrons	Wetland				33.33
Indigo Bunting	Passerina cyanea	Field/Shrub	0.17	0.17	0.33	
		Willow/Cottonwood Forest	0.17			
		Oak/Hickory Forest		0.17		
		Oak Woodland	0.50	0.33		
Killdeer	Charadrius vociferus	Field/Shrub			5.00	
Loggerhead Shrike	Lanius ludovicianus	Oak Woodland				0.17
Mallard	Anas platyrhynchos	Wetland				2.33

Appendix B. Continued

Species	Scientific Name	Habitat Type	Season			
			Spr	Sum	Fall	Win
Mourning Dove	*Zenaida macroura*	Field/Shrub		0.17		
		Wetland			0.17	
		Oak Woodland	0.33			
Northern Bobwhite	*Colinus virginianus*	Field/Shrub	0.17			
		Oak Woodland	0.17			
Northern Cardinal	*Cardinalis cardinalis*	Field/Shrub	1.00	0.50	0.50	2.33
		Willow/Cottonwood Forest	0.33	0.33		
		Oak/Hickory Forest	0.33	0.67	0.50	
		Wetland	0.67	0.33	0.17	0.67
		Oak Woodland	0.83	0.67	0.67	1.00
Northern Flicker	*Colaptes auratus*	Oak/Hickory Forest		0.17		
Northern Shoveler	*Anas clypeata*	Wetland				1.67
Orange-Crowned Warbler	*Vermivora celata*	Oak Woodland			0.17	

Appendix B. Continued

Species	Scientific Name	Habitat Type	Season			
			Spr	Sum	Fall	Win
Painted Bunting	*Passerina ciris*	Field/Shrub	0.17	0.33		
		Oak Woodland	0.50	0.33		
Pied-Billed Grebe	*Podilymbus podiceps*	Wetland	0.17			
Pileated Woodpecker	*Dryocopus pileatus*	Field/Shrub	0.33			
		Willow/Cottonwood Forest	0.17			0.67
		Wetland			0.17	
Prothonotary Warbler	*Protonotaria citrea*	Willow/Cottonwood Forest	0.17			
		Wetland	0.17	0.17	0.17	
Red-Bellied Woodpecker	*Melanerpes carolinus*	Field/Shrub		0.17	0.17	
		Willow/Cottonwood Forest	0.50	0.33		0.50
		Oak/Hickory Forest			0.67	0.67
		Wetland	0.33		0.83	0.67
		Oak Woodland	0.17		0.17	0.33

Appendix B. Continued

Species	Scientific Name	Habitat Type	Season			
			Spr	Sum	Fall	Win
Red-Headed Woodpecker	*Melanerpes erthrocephalus*	Field/Shrub	0.17			
		Wetland		0.17		
Red-Tailed Hawk	*Buteo jamaicensis*	Wetland			0.33	
Red-Winged Blackbird	*Agelaius phoeniceus*	Field/Shrub	0.17			
		Wetland	0.17			
Rose-Breasted Grosbeak	*Pheucticus ludovicianus*	Wetland	0.17			
Ruby-Crowned Kinglet	*Regulus calendula*	Willow/Cottonwood Forest				0.33
		Wetland				0.33
		Oak Woodland			0.50	
Ruby-Throated Hummingbird	*Archilochus colubris*	Field/Shrub		0.17		
		Willow/Cottonwood Forest	0.17			
		Oak Woodland	0.67			
Scissor-Tailed Flycatcher	*Tyrannus forficatus*	Field/Shrub	0.50			

Appendix B. Continued

Species	Scientific Name	Habitat Type	Season			
			Spr	Sum	Fall	Win
		Wetland		0.17		
Song Sparrow	*Melospiza melodia*	Field/Shrub				0.67
		Oak Woodland	0.17			0.33
Swainson's Warbler	*Limnothlypis swainsonii*	Willow/Cottonwood Forest	0.17			
Tufted Titmouse	*Parus bicolor*	Field/Shrub	0.17		0.50	
		Willow/Cottonwood Forest	0.83	0.17		0.50
		Oak/Hickory Forest	1.67		0.83	0.33
		Wetland	0.33			0.33
		Oak Woodland	0.33		0.17	
Turkey Vulture	*Cathartes aura*	Willow/Cottonwood Forest			0.17	
		Wetland	0.67			
White-Breasted Nuthatch	*Sitta carolinensis*	Willow/Cottonwood Forest	0.33	0.50		0.83
		Wetland	0.17			0.17

Appendix B. Continued

Species	Scientific Name	Habitat Type	Season			
			Spr	Sum	Fall	Win
		Oak Woodland	0.17			
White-Throated Sparrow	*Zonotrichia albicollis*	Willow/Cottonwood Forest			0.17	
		Wetland				0.17
		Oak Woodland				0.17
Willow Flycatcher	*Empidonax traillii*	Oak/Hickory Forest	0.17			
Winter Wren	*Troglodytes troglodytes*	Willow/Cottonwood Forest				0.17
Wood Duck	*Aix sponsa*	Willow/Cottonwood Forest	0.17			
		Wetland			2.17	
Yellow Warbler	*Dendroica petechia*	Willow/Cottonwood Forest	0.17			
		Wetland	0.33			
		Oak Woodland	0.17			
Yellow-Billed Cuckoo	*Coccyzus americanus*	Field/Shrub	0.17	0.67		
		Willow/Cottonwood Forest		0.17		

Appendix B. Continued

Species	Scientific Name	Habitat Type	Season Spr	Sum	Fall	Win
		Oak/Hickory Forest		0.17		
		Wetland		0.17		
		Oak Woodland		0.33		
Yellow-Rumped Warbler	*Dendroica coronata*	Field/Shrub				0.33
		Oak/Hickory Forest				0.33
		Wetland				0.50
		Oak Woodland			0.17	
Yellow-Throated Vireo	*Vireo flavifrons*	Wetland	0.17			
Yellow-Throated Warbler	*Dendroica dominica*	Willow/Cottonwood Forest		0.17		
		Wetland	0.17	0.17		

Appendix C. Relative abundance (no. animals/ha) of herpetofauna sampled at Tishomingo National Wildlife Refuge, Oklahoma, during the spring, summer and fall of 1996 and 1997.

			Season		
Species	Scientific Name	Habitat Type	Spring	Summer	Fall
Black Rat Snake	Elaphe obsoleta	Upland shrub		1.70	
Blanchard's Cricket Frog	Acris crepitans	Wetland	1.70	11.88	8.48
Copperhead	Agkistrodon contorttrix	Oak/Hickory Forest		1.70	
Fence Lizard	Sceloporus undulatus	Oak/Hickory Forest	1.70		
Five-lined Skink	Eumeces fasciatus	Oak/Hickory Forest	1.70		
Flathead Snake	Tantilla gracilis	Oak/Hickory Forest	1.70		
Ground Skink	Scincella lateralis	Oak/Hickory Forest	11.88		
Southern Leopard Frog	Rana utricularia	Willow/Cottonwood Forest		1.70	
Three-toed Box Turtle	Terrapene carolina	Oak/Hickory Forest	1.70		
Western Cottonmouth	Agkistrodon piscivorous	Grassland (with shrub)	1.70		
Western Ribbon Snake	Thamnophis proximus	Wetland	1.70		
Woodhouse's Toad	Bufo woodhousii	Willow/Cottonwood Forest		1.70	

Appendix D. Relative abundance (no. animals/100 trap nights) of small mammals snap trapped at Tishomingo National Wildlife Refuge, Oklahoma, during spring and summer of 1996 and 1997.

			Season			
Species	Scientific Name	Habitat	Spr 1996	Sum 1996	Spr 1997	Sum 1997
Deer Mouse	Peromyscus maniculatus	Agriculture		1.1	0.6	
		Grassland (With Shrub)			1.1	
		Willow/Cottonwood Forest		0.6	1.1	
		Oak/Hickory Forestland Shrub			1.1	
		Oak/Hickory Forest			1.7	
		Wetland			0.6	
Eastern Woodrat	Neotoma floridana	Agriculture			0.6	
		Willow/Cottonwood Forest			0.6	
		Oak/Hickory Forest	0.6	0.6	0.6	
Eliot's Short-Tailed shrew	Blarina hylophaga	Willow/Cottonwood Forest		1.1		

Appendix D. Continued

Species	Scientific Name	Habitat	Season			
			Spr 1996	Sum 1996	Spr 1997	Sum 1997
		Oak/Hickory Forestland Shrub			0.6	
Fulvous Harvest Mouse	Reithrodontomys fulvescens	Grassland (With Shrub)	1.1			
		Wetland	0.6			
Hispid Cotton Rat	Sigmodon hispidus	Grassland (With Shrub)	1.1	1.1		1.1
		Willow/Cottonwood Forest				0.6
		Oak/Hickory Forestland Shrub	6.7	2.8	1.1	1.7
		Wetland		0.6		
White-Footed Mouse	Peromyscus leucopus	Agriculture	1.1			
		Grassland (With Shrub)	0.6		1.1	
		Willow/Cottonwood Forest		1.1		1.1
		Oak/Hickory Forestland Shrub		0.6		0.6

Appendix D. Continued

Species	Scientific Name	Habitat	Season			
			Spr 1996	Sum 1996	Spr 1997	Sum 1997
		Oak/Hickory Forest	0.6			0.6
		Wetland		0.6	0.6	

Appendix E. Relative abundance (no. animals/100 operable scent-station nights) of mammals sampled at Tishomingo National Wildlife Refuge, Oklahoma, from fall 1996 to summer 1997.

			Season			
Species	Scientific Name	Habitat	Spring	Summer	Fall	Winter
Armadillo	*Dasypus novemcinctus*	Oak/Hickory Forest	7			
Bobcat	*Lynx rufus*	Willow/Cottonwood Forest			9	
		Agriculture				14
		Oak/Hickory Forest				7
Coyote	*Canis latrans*	Agriculture	25	7	22	29
		Field/Shrub				7
Eastern Cottontail	*Sylvilagus floridanus*	Field/Shrub				7
Feral Hog	*Sus scrofa*	Willow/Cottonwood Forest		13		
Fox	NA	Agriculture		7		14
Fox Squirrel	*Scurius Niger*	Willow/Cottonwood Forest		7	9	
		Oak/Hickory Forest	10	13	7	
House Cat	*Felis domesticus*	Field/Shrub		7		

Appendix E. Continued

Species	Scientific Name	Habitat	Season: Spring	Summer	Fall	Winter
		Oak/Hickory Forest		7		
Opossum	*Didelphis virginiana*	Willow/Cottonwood Forest			18	
		Oak/Hickory Forest	13	13		13
Raccoon	*Procyon lotor*	Willow/Cottonwood Forest		7	18	20
		Oak/Hickory Forest	20	13	20	7
		Agriculture	25	7	33	
		Field/Shrub		7		
Rodent	NA	Field/Shrub		7		
Weasel	NA	Oak/Hickory Forest				7
White-Tailed Deer	*Odocoileus virginianus*	Field/Shrub	46	13		7
		Oak/Hickory Forest	13	7	20	
		Agriculture		20	22	14

Appendix E. Continued

			Season			
Species	Scientific Name	Habitat	Spring	Summer	Fall	Winter
		Willow/Cottonwood Forest				20

VITA

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Master of Science

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