Conservation Biology Research Grants Program
Division of Ecological Services
Minnesota Department of Natural Resources

COMPARISONS OF FLOODPLAIN FOREST BIRD COMMUNITIES ADJACENT TO FOUR LAND USE TYPES AT MINNESOTA VALLEY NATIONAL WILDLIFE REFUGE

A Thesis

Presented to

the Faculty of the Graduate School

University of Missouri-Columbia

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Anthony W. Cubbedge

Dr. Charles H. Nilon Thesis Supervisor

May 1994

The undersigned, appointed by the Dean of the Graduate School, have examined the thesis entitled

COMPARISONS OF FLOODPLAIN FOREST BIRD
COMMUNITIES ADJACENT TO FOUR LAND USE TYPES
AT MINNESOTA VALLEY NATIONAL WILDLIFE REFUGE

presented by Anthony W. Cubbedge

a candidate for the degree of Master of Science

and hereby certify that in their opinion it is worthy of acceptance.

ACKNOWLEDGEMENTS

I am grateful to Dr. Charles Nilon for his assistance and support on this project. I would also like to thank Drs. John Faaborg and Ernie Wiggers for their assistance and patience in the preparation of this thesis.

Dr. Gary Krause, Ed Callahan, Brian Root and countless other graduate students supplied helpful suggestions along with statistical support.

I would also like to thank my field assistants, Larry Schonders, Julie Craigmile, Scott Hamilton, and John Triana.

Funding for this project was provided by the Missouri Agricultural Experiment Station, U.S. Fish and Wildlife Service, Minnesota Department of Natural Resources, and Missouri Cooperative Fish and Wildlife Research Unit.

A special thanks to my office mates, John Triana, Gwyn McKee, and Rachel Chambers. They were always supportive and lent an ear when I had a problem or needed to blow off some steam.

I am indebted to my parents, Jack and Libby Cubbedge, for all of their support and inspiration. They were the first to expose me to the great outdoors and instilled in me a love and respect for nature that I will take to my grave.

Finally, and most importantly, I thank my wife, Nancy, and my new son, Kyle. Nancy was always there for me and provided the endless love, encouragement, and support I needed to complete this

thesis. Kyle's arrival provided the extra incentive needed to wrap up the loose ends. I love you both!

ABSTRACT

Minnesota Valley National Wildlife Refuge is a 3239 ha greenway extending 55 km along the Minnesota River. The refuge is located within the 7-county Minneapolis-St. Paul metropolitan area. Floodplain forest is the most abundant terrestrial habitat on the refuge and is most vulnerable to the effects of urbanization. In 1992 I started a 2-year study comparing the winter and breeding bird communities of the four largest, floodplain forest stands on the refuge. My goal was to determine if bird species composition and abundance among the four stands was influenced by adjacent commercial, residential, industrial, and agricultural land uses. I counted birds on strip transects located in each of the four stands and in the adjacent land use areas.

Data from 1992 and 1993 indicated that the bird communities of the floodplain forest stands were distinct in species composition and density from those of the adjacent land uses, during the winter and breeding season. Adjacent land use did not appear to explain the patterns of differences observed for the winter floodplain forest birds. However, land use associated with the industrial area resulted in changes in the structure of adjacent floodplain forest and consequently the breeding bird community. Natural resource managers should recognize the potential consequences of habitat alterations resulting from adjacent land use practices.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

Chapter 1
Introduction and Study Area

Introduction

Protecting the integrity of wildlife habitats is crucial for maintaining viable wildlife communities, particularly on refuges in urban landscapes. The Minnesota Valley National Wildlife Refuge, situated within the Minneapolis/St. Paul Metropolitan area, is one of three urban National Wildlife Refuges in the United States (Blanchard, 1991). As an urban refuge, Minnesota Valley provides the residents of Minneapolis/St. Paul with a source of environmental education and outdoor recreational opportunities. As a wildlife refuge, the goals are to protect and preserve the unique habitats of the Minnesota Valley. Given the location of the refuge, the managers are concerned about the impacts of activities associated with the adjacent land uses.

A habitat of particular concern is the floodplain forest. Twenty percent of the refuge is floodplain forest, making it the most abundant terrestrial habitat (Minnesota Valley National Wildlife Refuge Draft E.I.S., 1978). These riparian forests are periodically inundated, bringing nutrient-rich sediment to the floodplain and exporting organic matter. As a result, floodplain forests have high species diversity, high species density, and high productivity (Mitch and Gosselink, 1986).

Floodplain forests are linear by nature and have large amounts of edge (Mitch and Gosselink, 1986). At the refuge, these forests are also surrounded by a matrix of land use types, resulting in small, isolated, linear stands. This may make the stands more vulnerable to changes from activities associated with development in the adjacent areas (Soule, 1986; Shafer, 1990).

The refuge contains nearly all the large tracts of floodplain forest in the Minneapolis-St. Paul area, so these forests may play a key role in maintaining the avian diversity of the Twin Cities region (M. Mitchell, personal communication, 1992). The avian communities of Minnesota Valley National Wildlife Refuge were censused in 1978 as part of the draft environmental impact statement. Warner (1979) identified 97 avian species that used the refuge floodplain forest stands, sixty of which are considered neotropical migrants (Finch, 1991).

Studies have documented the impacts of urban development on bird communities (Geis, 1974; DeGraaf and Wentworth, 1986). Geis (1974) noted that species richness decreased and the absolute number of birds increased in Columbia, Maryland as it developed. The most obvious change in the bird community was the increase in numbers of exotic species. DeGraaf and Wentworth (1986) determined that difference in species composition and avian guilds among neighborhoods depended mostly on the degree of natural habitat alteration. Changes in the avian communities of adjacent habitats may have repercussions for the bird communities of the forested habitats next to them.

Studies have documented the effect of urban development and land use practices on bird communities of adjacent forest habitats (Dowd, 1992; Smith and Schaefer, 1992). Dowd (1992) suggested that urban development encroaches upon and degrades the forest habitat leading to a bird community resembling that of an urban environment. Smith and Schaefer (1992) identified adjacent land use as a factor responsible for avian community differences between their forested sites adjacent to rural and urban land use.

Tilghman (1987) also examined the effects of urban development on forest bird communities. Her study indicated that the size of the woodlands was the most important variable in explaining differences in the number of species and species diversity, with larger areas supporting more species with greater diversity.

The concerns of forest size, forest fragmentation, and juxtaposition of habitats have been active areas of recent ecological studies (Faaborg et al., in press). Some of the problems associated with habitat fragmentation include habitat loss, habitat alteration, increase in edge habitat and edge effects, and habitat isolation (Harris, 1984; Saunders et al., 1991; Shafer, 1990; Faaborg et al., in press). Avian population declines have been linked to these consequences of fragmentation (Ambuel and Temple, 1983; Askins et al., 1990; Finch, 1991). These concerns may be magnified in the urban ecosystem.

Two aspects of habitat fragmentation in the urban environment that may be of particular concern to refuge I managers are habitat structural changes and the increase in nest predator/parasite abundance. One study has documented the habitat changes of floodplain forest stands in the urban environment (Hobbs, 1988). Hobbs documented changes in tree species composition and vegetation structure of floodplain forest remnants adjacent to urban development. She noted a shift in species composition of lowland stands to more xeric species, and suggested that succession from wet to Mesic conditions had occurred with the urbanization around the floodplain forests. She also suggested that an exotic plant species, European buckthorn (Rhamnus frangula), may affect the forest composition and structure. Given the linear I nature of floodplain forests, the habitat structure of the refuge forests may be particularly vulnerable to the activities in the adjacent areas.

With small forest size and high amounts of edge, the refuge floodplain forest bird communities may be vulnerable to predation and parasitism. In general, predation rates are often higher in small forest fragments than in larger ones and higher near edge in forested areas than in the interior (Wilcove, 1985; Small and Hunter, 1988; Yahner and Scott, 1988). The brown-headed cowbird (scientific names of birds listed in appendix A), a brood parasite, is also more abundant along forest edge than interior and parasitism rates are usually higher near forest edges (Brittingham and Temple, 1983; Robinson et al., 1993).

Higher nest predation has been documented in woodlots adjacent to developed areas. Using artificial nests, Wilcove (1985) found nest predation rates were 70.5% in woodlots near suburban neighborhoods compared to 47.5% for woodlots in isolated, rural areas. He also suggested dogs (*Canis familiaris*), cats (*Felix cattus*), and rats (*Rattus* spp.) from the adjacent areas probably add to the predator base in urban landscapes. Soule et. al. (1988) suggested that development of areas adjacent to chaparral habitat types resulted in an increase in a number of mammalian predators.

These studies suggest at least three different aspects of the wildlife communities that may be impacted by the adjacent land use patterns: changes in the bird communities, alterations in the vegetative structure of the forests, and the potential increase in predators/parasites.

The Minnesota Valley National Wildlife Refuge provides a unique opportunity to study the impacts of adjacent land use. The refuge, extending from the Minneapolis International Airport to the rural town of Jordan, is adjacent to many land use types. With insight on the impacts of adjacent land use practices, attempts could be made to buffer and better protect refuge habitats. Consequently, the goal of this project was to determine some of the impacts of adjacent land use on floodplain forest bird communities at Minnesota Valley National Wildlife Refuge.

I set out to answer two questions for the winter and breeding bird communities during the course of this study:

1) Does the floodplain forest support a bird community that is distinct from the adjacent land use areas?

2) Are there differences in the bird communities of the floodplain forests that are adjacent to different land use practices?

By achieving the following objectives, I should be able to answer these questions: 1) determine breeding and wintering bird use of floodplain forest habitats at Minnesota Valley National Wildlife Refuge; 2) determine if the floodplain forest bird communities were distinct from the bird communities of the adjacent land uses; 3) determine the impacts of adjacent land use on floodplain forest bird communities; 4) quantify habitat structure of floodplain forest on the refuge and relate habitat structure to use by floodplain forest birds; 5) quantify the adjacent land use patterns and relate them to use by floodplain forest birds; and, 6) relate the abundance of potential mammalian and avian nest predators/parasites to land uses adjacent to the refuge.

Study area

This study was conducted at the Minnesota Valley National Wildlife Refuge. Located within the metropolitan area of Minneapolis-St. Paul, Minnesota Valley is one of three urban national wildlife refuges in the nation (Figure 1). The refuge is situated along a 54.8 km stretch of the Minnesota River-from Fort Snelling to Jordan, Minnesota. It is approved for 7,490 ha and the refuge currently owns or leases 3,239 ha (M. Mitchell, personal communication, 1992).

Four sites were selected based on the following criteria: 1) a floodplain forest >20 ha in size, and 2) their juxtaposition to commercial/service, industrial, residential, and agricultural land use. The four study sites were: 1) Long Meadow Lake (CS), adjacent to commercial/service land use (28 ha); 2) Bloomington Ferry (RS), adjacent to residential land use (27 ha); 3) Port Cargill (IN), adjacent to industrial land use (30 ha); and, 4) Louisville Swamp (AG), adjacent to agricultural land use (20 ha) (Figure 1). Port Cargill is not on refuge land. No refuge site of adequate size was adjacent to industrial land use, so the refuge biologist, Mary Mitchell, suggested this site. These four land use types were selected because they are well represented in urban and urbanizing areas.

Land use variables were measured within 1 km of the floodplain forests at each site (Table 1.1). Land use types were classified using the existing refuge's geographic information system (G.I.S.) and updated with land use maps and aerial photos from Carver, Scott, Hennepin, and Dakota counties.

Each site contained three avian transects in the floodplain forest stands (CSI, INI, RSI, AGI) and three avian transects in the adjacent land use areas (CSO, INO, RSO, AGO). The transects were 100 m long and 50 m on each side, yielding an area of 1 ha for each transect.

Figure 1.1. Location of the Minnesota Valley National Wildlife Refuge, Minneapolis, Minnesota (Minnesota Valley National Wildlife Refuge Draft Environmental Impact Statement, 1978).

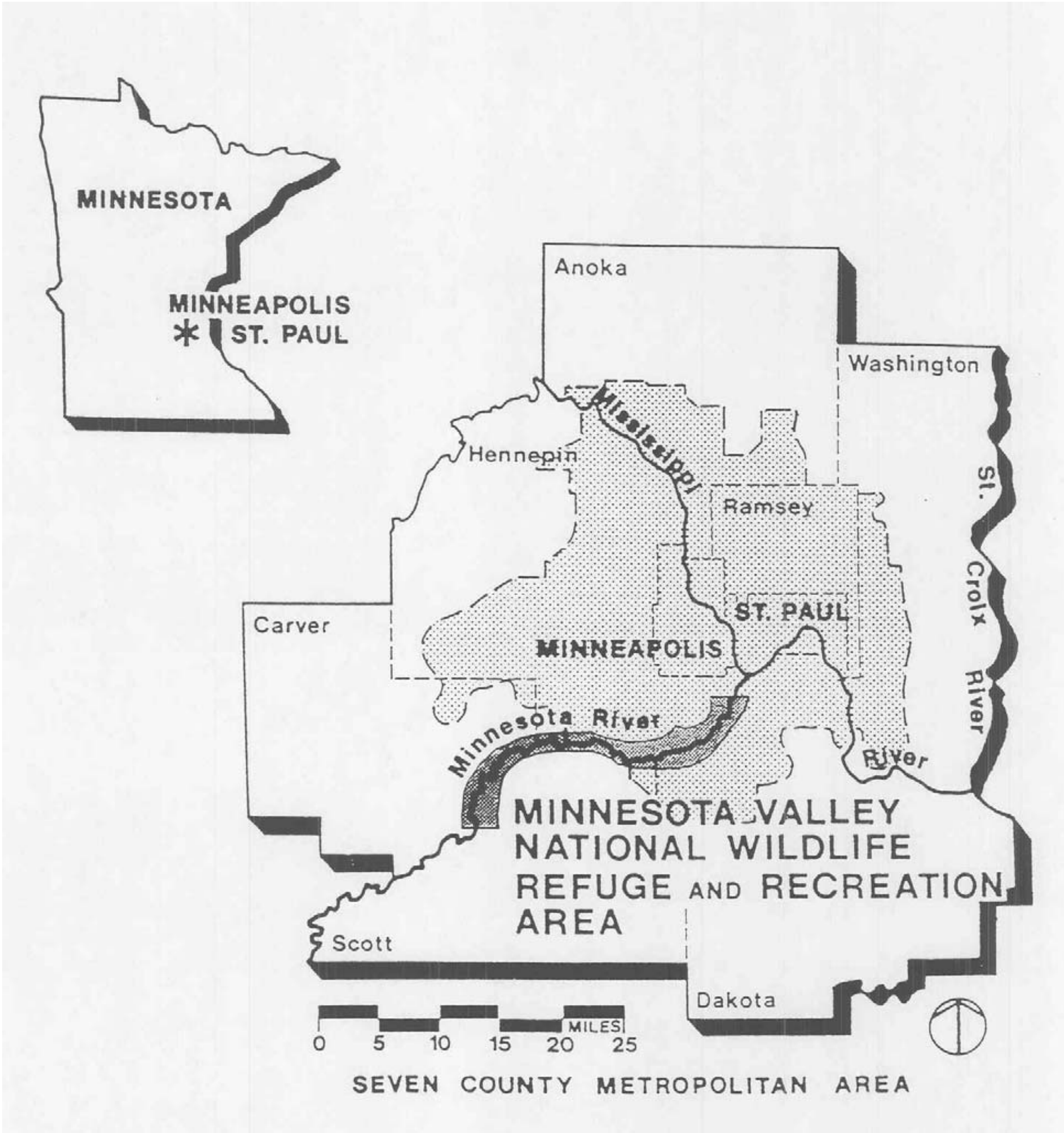

MINNESOTA
MINNEAPOLIS
ST. PAUL
Anoka
Washington
Hennepin
Mississippi
Ramsey
St. Croix River
Carver
ST. PAUL
MINNEAPOLIS
Minnesota River
River
MINNESOTA VALLEY
NATIONAL WILDLIFE
REFUGE AND RECREATION
AREA
Scott
Dakota
MILES
0 5 10 15 20 25
SEVEN COUNTY METROPOLITAN AREA

Table 1.1. Percentage of land use types within 1 km of the center of the floodplain forest sites on Minnesota Valley National Wildlife Refuge.

	Sites			
Land Use Type	CS	IN	RS	AG
Refuge/Park	89	70	67	55
Commercial/ Service	10			4
Agricultural	1		5	39
Industrial		25		1
Residential		5	22	1
Recreational			6	

LITERATURE CITED

Ambuel, B. and Temple, S.A., 1983. Area-dependent changes in the bird communities and vegetation of Southern Wisconsin forests. Ecology, 64:1057-1068.

Askins, R.A., Lynch, J.F., and Greenberg, R., 1990. Population declines in migratory birds in Eastern North America. In: D.M. Powers (Editor), Current ornithology, Vol. 7, Plenum Publishing Corp., New York, N.Y., pp. 1-57.

Blanchard, B., 1991. Wildlife in a changing world: urban challenges for the Fish and Wildlife Service. In: L.W. Adams and D.L. Leedy (Editors) Wildlife conservation in metropolitan environments. Proceedings of a National Symposium on Urban Wildlife. Natl. Inst. Urban Wildl., Columbia, MD, pp.15-18.

Brittingham, M.C. and Temple, S.A., 1983. Have cowbirds caused forest songbirds to decline? Bioscience, 33:31-35.

DeGraaf, R.M. and Wentworth, J.M., 1986. Avian guild structure and habitat associations in suburban bird communities. Urban Ecol., 9: 399-412.

Dowd, C., 1992. Effect of development on bird species composition of two urban forested wetlands in Staten Island, New York. J. Field Ornithol., 63:455-461.

Faaborg, J., Brittingham, M., Donovan, T., and Blake, J., In press. Neotropical migrants responses to habitat fragmentation in the temperate zone.

Finch, D.M., 1991. Population ecology, habitat requirements, and conservation of neotropical migratory birds. United States Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Col. 26pp.

Geis, A.D., 1974. Effects of urbanization and type of urban development on bird populations. In: J.H. Noyes and D.R. Progulski (Editors), Wildlife in an urbanizing environment. Univ. Mass. Amherst, Mass., pp. 97-105.

Harris, L.D., 1984. The fragmented forest: Island biogeographic theory and the preservation of biotic diversity. University of Chicago Press, Chicago, Ill. 211 pp.

Hobbs, E.R., 1988. Using ordination to analyze the composition and structure of urban forest islands. For. Ecol. Manage., 23: 139-158.

Minnesota Valley National Wildlife Refuge Draft E.I.S., 1978. Division of Refuges and Wildlife Planning Section. Region 3, Minneapolis-St. Paul, Minn.

Mitch, W.J. and Gosselink, J.G., 1986. Wetlands. Van Nostrand Reinhold, New York, N.Y. 537pp.

Robinson, S.K., Grzybowski, J.A., Rothstein, S.I., Brittingham, M.C., Petit, L.J., and Thompson, F.R., 1993. Management implications of cowbird parasitism on neotropical migrant songbirds. In: D.M. Finch and P.W. Stangel (Editors), Status and management of neotropical migratory birds, U.S.D.A. Forest

Service General Technical Report, RM-229, Fort Collins, Col., pp. 93-102.

Saunders, D.A., Hobbs, R.J., and Margules, C.R., 1991. Biological consequences of ecosystem fragmentation: a review. Conserv. Biol., 5:18-32.

Shafer, C.L., 1990. Nature reserves: Island theories and conservation practice. Smithsonian Institute Press, Washington D.C., 189 pp.

Small, M.F., and Hunter, M.L., 1988. Forest fragmentation and avian nest predation in forested landscapes. Oecologia, 76:62-64.

Smith, R.J. and Schaefer, J.M., 1992. Avian characteristics of an urban riparian corridor. Wilson Bull., 104:732-738.

Soulé, M.E., 1986. Conservation biology: The science of scarcity and diversity. Sinauer Associates Inc., Sunderland, Mass. 233 pp.

Soulé, M.E., Bolger, D.T., Alberts, A.C., Wright, J., Sorice, M. and Hill, S., 1988. Reconstructed dynamics of rapid extinctions of chaparral-requiring birds in urban habitat islands. Conserv. Biol., 2: 75-92.

Tilghman, N.G., 1987. Characteristics of urban woodlands affecting breeding bird diversity and abundance. Landscape Urban Plann., 14: 481-495.

Warner, D.W., 1979. Wildlife inventory of the Lower Minnesota River Valley. Report to U. S. Fish and Wildlife Service, Twin Cities, Minn. (unpublished).

Wilcove, D.S., 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology, 66: 1211-1214.

Yahner, R. and Scott, D.P., 1988. Effects of forest fragmentation on depredation of artificial nests. J. Wild. Manage., 52:158-161.

Chapter 2

The Winter Bird Community

Introduction

Little information is available on winter bird use of floodplain forest stands. Winter birds are seeking areas that provide thermoregulatory and forage benefits (Yahner, 1981; Tilghman, 1987). The floodplain forests of Minnesota Valley provide winter birds with thermoregulatory cover. These forest stands are also adjacent to many urban habitats, such as residential areas with feeders and shrubs and industrial areas with spilled grain, which may supplement the forage needs of wintering birds.

Evidence suggests that urban land use has an impact on bird communities of adjacent forest habitats (Tilghman, 1987; DeGraaf, 1991; Smith and Schaefer, 1992). Tilghman (1987) determined that the numbers of winter bird species and their density were related to an increase in the density of buildings adjacent to woodlands. She suggested that this increase was due to the presence of feeding stations in residential yards. Some researchers (Freedman and Riley, 1980; Bock and Lepthien, 1976) have noted increases in the population of certain winter birds (i.e. blue jays, cardinals, and mourning doves) in urban areas. They suggested that winter bird-feeding may account for these increases.

The amount of native habitat alteration was another impact of urban land use (DeGraaf, 1991). Residential areas lacking natural woodland habitats did not support the insectivorous component of the bird community present in areas with woodlands.

Smith and Schaefer (1992) provided the best insight on winter bird community responses to adjacent land use. Comparing riparian corridors adjacent to urban and rural land use, they observed winter bird density to be higher in the urban corridor. The birds occurring here were mostly omnivores, and feed on or close to the ground. Blue jays, northern cardinals, and American robins had higher densities at the urban riparian corridor. I would expect to see similar patterns in the winter bird communities at Minnesota Valley.

The Minnesota Valley National Wildlife Refuge is located within an urban landscape. The refuge managers are interested in expanding and/or buffering the habitats to maintain their integrity. This is particularly true for the floodplain forests, which are linear habitats with high amounts of edge. The refuge forests provide the wintering birds with a forested habitat in a matrix of land use components. The adjacent land use may have an impact on the bird communities wintering in these forests.

During 1992 and 1993, winter bird counts were conducted to collect data on the bird communities of floodplain forests adjacent to four land use types and within the land use areas themselves. This allowed me to explore the potential impacts of adjacent land use practices on the winter bird communities. Two questions were guiding the research of this study:

1) Does the floodplain forest support a winter bird community that is distinct from the adjacent land use areas?

2) Are there differences in the winter bird communities of the floodplain forests adjacent to commercial/service, industrial, residential and agricultural land use practices?

To help answer this question I posed the following hypotheses:

1) H_o: There is no difference in total bird density, seed eating/omnivore density, insectivore density, introduced species density, and native species density among the floodplain forest stands adjacent to the four land uses.

2) H_o: There is no difference in mean avian richness among the floodplain forest stands adjacent to the various land uses.

Study Area

The study area for the winter bird census is the same as described in chapter 1, except the sites in the adjacent land use areas (CSO, INO, RSO, AGO) had not been established in 1992. The industrial floodplain forest site (INI) was not censused in the winter of 1992 because I did not have permission to use this site.

Methods

Winter bird counts

Winter counts were conducted from 7-14 January 1992 and 9-16 January 1993 using the strip transect method (Conner and Dickson, 1980). The transects at each site were walked 6 times during the winter season from sunrise to 1100 hrs and all birds seen or heard were recorded. For winter counts, the time of day is not as critical as breeding bird surveys, but weather is an important factor (Conner and Dickson, 1980). Stormy or windy days were avoided during these surveys. The two field observers for each year had a college ornithology course and were trained in the data recording procedures.

Statistical analysis

A nonparametric analysis of variance (ANOVA) was used to compare the winter bird communities. All the individual avian species densities were combined to calculate total bird (TOTBD) density. The avian species were also grouped based on their foraging guilds ((seed-eating/omnivores = SDOMNI, and insectivores = INSECT) (DeGraaf, 1991)) and whether they were native (NATV) or introduced (INTRO) species (Appendix B). By looking at these groupings, I could determine which attributes of the avian community appeared to be affected by land use practices. Comparisons of the mean number of detections of these groups and individual species were then made among the four sites on rank-transformed data with ANOVA procedures using the SAS statistical package (SAS Institute Inc., 1985). Fisher's protected least significant differences multiple comparisons (LSD's) were used to compare means.

Results

Winter 1992

During the winter of 1992 three floodplain forest sites were censused: RSI, AGI, and CSI. Twelve species were observed on the sites. Mean avian density ranged from 0 to 4.33 birds/ha (Table 2.1). Total bird detections numbered 265 with black-capped chickadee and white-breasted nuthatch being the most abundant winter residents, accounting for 460 and 250 of the total detections respectively.

Six species were detected at all three sites, but two species occurred exclusively at one site (Table 2.1). Common redpoll detections were restricted to AGI, while the American crow was only detected at CSI. All the species detected at RSI also occurred at AGI or CSI or at both sites. RSI accounted for 540 (143) of the 265 detections at all three sites.

There was no difference in mean species richness among the sites (Table 2.2). There were differences in TOTBD ($F=21.02$, $\underline{P}=0.0001$, $df=2$) and SDOMNI ($F=20.06$, $P=0.0001$, $df=2$) among sites.

Table 2.1. Avian densities (birds/ha) for life history groupings and individual species in floodplain forest sites on the Minnesota Valley National Wildlife Refuge during winter season, 1992.

	Sites		
Species	AGI	RSI	CSI
TOTBD*	2.67b	7.94a	4.11b
INSECT	1.72	2.78	1.78
SDOMNI*	0.83c	5.06a	2.22b
AMCR		0 0	0.17
BCCH*	0.50c	4.33a	2.00b
BLJA	0.06	0.17	0
BRCR	0.11	0	0.06
CORE	0.28	0	0
DOWO	0.44	0.44	0.56
GCKI	0.11	0.11	0.11
HAWO	0.17	0.11	0.33
NOCA*	0b	0.56a	0.06b
PIWO	0.06	0	0.06
RBWO	0.06	0.11	0.11
WBNU*	0.89b	2.11a	0.67b

* Differences among sites (P < 0.05)

Values with different letter are different (P < 0.05)

Table 2.2. Mean species richness of the floodplain forest sites by transect and total richness for the sites during the winter season, 1992.

Species richness	Sites		
	RSI	CSI	AGI
Average number of species per transect	6.33	7.00	6.67
Total richness for the site	10	10	8

RSI had a higher ($P < 0.05$) TOTBD density than A GI and CSI (Table 2.1). SDOMNI also had the highest ($P < 0.05$) density at RSI.

The black-capped chickadee ($F=23.07$, $P=0.0001$, $df=2$) and northern cardinal ($F=10.10$, $P=0.0002$, $df=2$) showed differences among sites in mean avian density (Table 2.1). The black-capped chickadee and northern cardinal had higher ($P< 0.05$) mean density at RSI than CSI or AGI (Table 2.1).

Winter 1993

Sixteen species were observed in the floodplain forests and the adjacent areas. Mean density ranged from 0 to 24.22 birds/ha with 992 total detections for all sites (Tables 2.3 and 2.4) .

Fourteen species were observed at the forested sites, seven of which were not observed in the adjacent areas (Table 2.5). Total detections in the floodplain forest numbered 465 and densities ranged from 0 to 13.89 birds/ha. Four species were detected at all the floodplain forest sites, and nine species were found exclusively at one site (Table 2.3). RSI and INI each had three species detected only at these sites, but there was no difference in mean species richness among the sites (Table 2.6).

At INI, seven species were observed with 303 total detections. Of the 303 detections, 250 (83%) were European starlings encountered on one day. This site was also the only forest where the American crow, European starling, and red-tailed hawk were observed.

Table 2.3. Avian densities (birds/ha) for life history groupings and individual species at the floodplain forest sites during the winter season, 1993.

	Sites			
Species	AGI	RSI	INI	CSI
TOTBD	2.77	2.50	15.44	3.72
INSECT	1.89	1.05	0.77	1.11
SDOMNI*	0.89b	1.44b	0.72b	2.50a
INTRO	0	0	13.89	0
NATV*	2.78ab	2.50abc	1.55bc	3.72a
AMCR	0	0	0.11	0
ATSP	0	0	0	0.06
BAOW	0	0	0	0.11
BCCH*	0.89b	1.06b	0.66b	2.00a
BLJA*	0b	0.22a	0b	0b
BRCR*	0.39a	0b	0b	0b
DEJU	0	0.11	0	0
DOWO	0.17	0.17	0.22	0.11
EUST	0	0	13.89	0
HAWO	0.44	0.11	0.28	0.50
NOCA*	0b	0.06b	0b	0.44a
RBWO	0	0.11	0	0
0RTHA	0	0	0.06	0
WBNU*	0.89a	0.67ab	0.28b	0.50b

* Differences among sites ($P < 0.05$)

Values with different letters are different ($P < 0.05$)

Table 2.4. Avian densities (birds/ha) for life history groupings and individual species at the adjacent land use sites during the winter season, 1993.

	Sites			
Species	AGO	RSO	INO	CSO
TOTBD*	0.39b	1.44ab	26.94a	0.50b
INSECT	0	0.06	0	0.06
SDOMNI*	0.39b	1.39ab	26.94a	0.44b
INTRO*	0c	1.00b	26.94a	0.11c
NATV	0.39	0.44	0	0.39
AMCR	0	0.22	0	0
ATSP	0.39	0	0	0.06
BCCH	0	0	0	0.17
BLJA	0	0.11	0	0
DOWO	0	0	0	0.06
HOSP*	0c	1.00b	24.22a	0.11c
NOCA	0	0.06	0	0.11
RODO*	0b	0b	2.72a	0b
WBNU	0	0.06	0	0

*Differences among sites ($P < 0.05$)

values with different letters are different ($P < 0.05$)

Table 2.5. Avian densities (birds/ha) for life history groupings and individual species at the pooled forested and adjacent land use sites during the winter season, 1993.

	Sites	
Species	Floodplain forest	Adjacent land use
TOTBD*	6.11	7.32
INSECT*	1.21	0.03
SDOMNI*	1.39	7.29
INTRO*	3.47	7.01
NATV*	2.64	0.31
AMCR	0.03	0.06
ATSP	0.01	0.11
BAOW	0.03	0
BCCH*	1.14	0.04
BLJA	0.06	0.03
BRCR*	0.10	0
DEJU	0.03	0
DOWO*	0.17	0.01
EUST	3.47	0
HAWO*	0.33	0
HOSP*	0	6.33
NOCA	0.13	0.04
RBWO	0.03	0
RODO*	0	0.68
RTHA	0.01	0
WBNU*	0.58	0.01

* Differences between sites ($P < 0.05$)

Table 2.6. Mean species richness of the floodplain forest and adjacent land use sites by transect and total richness for the sites during the winter season, 1993.

Species richness	RSI	CSI	AGI	INI	RSO	CSO	AGO	INO
	Sites							
Mean number of species per transect	5.33	5.67	4.67	5.00	2.33a	2.33a	0.33b	1.33ab
Total richness for the site	8	7	5	7	5	5	1	5

Values with different letters are different ($P < 0.05$)

Nine species were observed in all the adjacent land use areas. Two of these, the house sparrow and rock dove, were unique to the adjacent land use areas. Five hundred and twenty seven birds were detected in the areas adjacent to the floodplain forests with densities ranging from 0 to 24.22 birds/ha (Table 2.4).

Two species, the house sparrow and rock dove, were observed at INO, with 485 detections. They accounted for 92% of the detections at all the adjacent land use sites. There was a difference ($F=4.71$, $P=0.035$, $df=3$) in mean species richness among the adjacent land use sites. RSO and CSO had a higher ($P < 0.05$) mean species richness than AGO (Table 2.6).

Avian density was pooled for the floodplain forest and adjacent land use sites and compared to determine if their bird communities were distinct. Differences in mean avian density were detected for TOTBD ($F=15.64$, $P=0.0001$, $df=1$), INSECT ($F=77.88$, $P=0.0001$, $df=1$), SDOMNI ($F=4.64$, $P=0.033$, $df=1$), INTRO ($F=31.02$, $P=0.0001$, $df=1$), NATV ($F=83.13$, $P=0.0001$, $df=1$), black-capped chickadee ($F=108.02$, $P=0.0001$, $df=1$), brown creeper ($F=8.50$, $P=0.0042$, $df=1$), downy woodpecker ($F=10.55$, $P=0.0015$, $df=1$), hairy woodpecker ($F=32.38$, $P=0.0001$, $df=1$), house sparrow ($F=39.44$, $P=0.0001$, $df=1$), rock dove ($F=4.86$, $P=0.0292$, $df=1$), and white-breasted nuthatch ($F=65.49$, $P=0.0001$, $df=1$) (Table 2.5). INSECT, black-capped chickadee, brown creeper, downy i woodpecker, hairy woodpecker, and white-breasted nuthatch had higher ($P < 0.05$) mean densities at the forested sites than their adjacent areas. TOTBD, SDOMNI, INTRO, rock dove and house sparrow density was higher (P <

0.05) in the adjacent land use areas than the floodplain forests. There was also a difference (F-81.09, P-0.0001, df=7) in the mean species richness between the floodplain forest and adjacent land use sites (Table 2.7). The floodplain forest sites had higher ($P < 0.05$) mean species richness.

SDOMNI (F=5.61, P=0.0001, df=6), NATV (F=2.38, P=0.0325, df=6), black-capped chickadee (F=4.03, P=0.001, df=6), blue jay (F=2.88, P=0.011, df=6), brown creepers (F=8.50, P=0.0001, df=6), northern cardinal (F=5.87, P=0.0001, df=6), and white-breasted nuthatch (F=3.38, P=0.0039, df=6) showed differences in mean density among the floodplain forest sites (Table 2.3). No differences were detected for TOTBD and INSECT, while SDOMNI, black-capped chickadee, and northern cardinal had the highest ($P < 0.05$) mean density at CSI. Brown creeper and white-breasted nuthatch had higher ($P < 0.05$) densities at AGI and blue jay density was higher ($P < 0.05$) at RSI.

At the adjacent land use sites, TOTBD (F=4.37, P=0.0005, df=6), SDOMNI (F=5.61, P=0.0001, df=6), INTRO (F=10.57, P=0.0001, df=6), house sparrow (F=11.81, P=0.0001, df=6) and rock dove (F=4.86, P=0.0002, df=6) showed differences in mean avian density (Table 2.4). No differences were detected for INSECT and NATV, while the highest ($P < 0.05$) mean avian density for TOTED, SDOMNI, INTRO, house sparrow, and rock dove occurred at INO.

Table 2.7. Mean species richness of the pooled floodplain forest and adjacent land use sites by transect and total species richness for the sites during the winter season, 1993.

	Sites	
Species richness	Floodplain forest	Adjacent land use
Mean number of species per transect*	5.17a	1.58b
Total richness for the site	14	9

* Differences between sites ($P < 0.05$)

Discussion

Two questions were guiding the research of this winter bird study. First, does the floodplain forest support a bird community that was distinct from the adjacent land use areas? I found that the floodplain forest did support a bird community that was distinct from the adjacent land use areas. Higher mean species richness was observed at the floodplain forest sites. There was also higher INSECT and NATV densities in the floodplain forest stands. The adjacent land use sites had higher TOTED, SDOMNI, and INTRO densities. This was due to the high number of detections of house sparrows and rock doves, a phenomenon Johnsen and VanDruff (1987) also observed during winter in the urban environments they studied.

Tilghman (1987) reported that urban woodlands supported a greater variety and density of bird species than other urban habitats. Urban woodlands provide the birds with protection from the winter thermal extremes, especially the wind. These areas also provide a variety of insects as well as being close to the urban areas where supplemental food resources such as refuse and bird feeders are available. As a result, these birds may, at times, move into the adjacent habitats. This may be occurring for species like the white-breasted nuthatch, Northern cardinal, and blue jay which were observed in the adjacent areas in very low densities.

DeGraaf (1991) emphasized the need for retaining native woodlands in urban residential areas as a means of maintaining the insectivorous component of urban bird communities. I agree with this, as very few insectivores were observed in the adjacent areas I censused.

The second question concerned the potential impacts of adjacent land use on the floodplain forest bird communities. Adjacent land use did not appear to affect the winter bird communities of the floodplain forests next to them . There was no difference in species richness among the floodplain forest sites in 1992 and 1993. TOTBD and SDONINI densities were higher ($P < 0.05$) at RSI in 1992. Tilghman (1987) suggested that residential bird-feeders may account for higher species densities and richness in forests adjacent to this habitat type. However, I did not observe this pattern in the 1993 data. There was no difference in TOTBD density among the sites in 1993 and SDOMNI densities were higher ($P < 0.05$) at CSI and not RSI as in 1992. The patterns of difference in the bird community do not appear to relate to the adjacent land use.

Winter birds often move to take advantage of patchy food supplies, so the type of adjacent land use may not be a factor for winter bird communities. A factor that may explain some of the variation between years is the bridge construction and forest removal at the site adjacent to residential land use. This site contained the refuge's largest contiguous tract of floodplain forest. The bird transects were located at the end of a 48 ha forest in 1992. Construction of the new bridge began in the spring of 1992. After construction, the bird transects were centrally located in a 27 ha floodplain forest stand. Tilghman (1987) demonstrated that some wintering birds showed a preference for larger woodlands. The black-capped chickadee and whitebreasted nuthatch were two species that showed this preference and also had higher densities at this site in 1992.

My study indicates that the floodplain forest supports a winter bird community that is different from their adjacent areas and also that adjacent land use did not appear to explain the patterns of differences observed for the winter floodplain forest birds. Future studies should continue to monitor the bird communities as the land use patterns adjacent to the refuge change.

LITERATURE CITED

Bock, C.E. and Lepthien, L.W., 1976. Changing winter distribution and abundance of the blue jay. Am. Midl. Nat., 96: 232-236.

Conner, R.N. and Dickson, J.A., 1980. Strip transect sampling and analysis for avian habitat studies. Wildl. Soc. Bull., 8: 4-10.

DeGraaf, R.M., 1991. Winter foraging guild structure and habitat associations in suburban bird communities. Landscape Urban Plann., 21:173-180.

DeGraaf, R.M. and Wentworth, J.M., 1981. Urban bird communities and habitats in New England. Trans. North Am. Wildl. Nat. Resour. Conf., 46:396-413.

Freedman, B. and Riley, J.L., 1980. Population trends of various species of birds wintering in southern Ontario. Ont. Field Biol., 34:49-79.

Johnsen, A.M. and VanDruff, L.W., 1987. Summer and winter distributions of introduced bird species and native bird species richness within a complex urban environment. In: L.W. Adams and D.L. Leedy (Editors), Integrating man and nature in the metropolitan environment. Natl. Inst. Urban Wildl., Columbia, MD, pp.123-127.

NOAA, 1992. Local climatological data, January-Minneapolis/St. Paul, Minn., National Oceanic and Atmospheric Administration, Asheville, N.C. 4 pp.

NOAA, 1993. Local climatological data, January-Minneapolis/St. Paul, Minn., National Oceanic and Atmospheric Administration, Asheville, N.C. 4 pp.

SAS Institute Inc., 1989. SAS user's guide: statistics, version 6 edition. SAS Institute Inc., Cary, N.C. 1686 pp.

Smith, R.J. and Schaefer, J.M., 1992. Avian characteristics of an urban riparian corridor. Wilson Bull., 104:732-738.

Tilghman, N.G., 1987. Characteristics of urban woodlots affecting winter bird diversity and abundance. For. Ecol. Manage., 21:163-175.

Yahner, R.S., 1981. Avian winter abundance patterns in farmstead shelterbelts: weather and temporal effects. J. Field Ornithol. 52:50-56.

Chapter 3
The Breeding Bird Community

Introduction

Protecting the integrity of wildlife habitats is crucial to maintaining viable wildlife communities, particularly for refuges in urban environments. The Minnesota Valley National Wildlife Refuge is located within such an urban landscape. It is designated as an urban National Wildlife Refuge and therefore has active environmental education and interpretation programs as well as the goal of protecting and preserving the unique habitats of the Minnesota Valley (Blanchard, 1991).

A particular habitat of concern for the refuge managers at Minnesota Valley is the floodplain forests, located along the Minnesota River. These forests, composed of cottonwood (Populus deltoides), black willow (Salix nigra), American elm (Ulmus americana), and silver maple (Acer saccharinum), represent 20% of the refuge lands (Minnesota Valley National Wildlife Refuge Draft E.I.S., 1978). The floodplain forests are periodically inundated, bringing nutrient-rich sediment to the floodplain and exporting organic matter. As a result, floodplain forests have high species diversity, high species densities, and high productivity (Mitch and Gosselink, 1986).

Riparian forests provide valuable and diverse habitat for many wildlife species (Fredrickson, 1979). These

<PAGE 37 MISSING FROM HARD COPY>

communication, 1992). Refuge managers are interested in expanding and/or buffering the refuge when the possibilities arise. Most of the lands available for acquisition are within the floodplain and include floodplain forest tracts. Given the linear nature of floodplain forest and the high amounts of edge, concerns have been raised about the impacts of adjacent land use practices on the avian communities.

These concerns are basically issues of habitat fragmentation and isolation; topics receiving much attention in recent ecological literature (Faaborg et al., in press). Some of the problems associated with habitat fragmentation include habitat loss, habitat alteration, increase in edge habitat and edge effects and habitat isolation (Harris, 1986; Saunders et al. 1991; Shafer, 1990; Faaborg et al., in press). These habitat fragmentation issues have been linked to recent avian population declines (Ambuel and Temple, 1983; Askins et al., 1990; Finch, 1991). In an urban environment, habitat fragmentation is a given.

Land use activities and urban development have had substantial impacts on bird communities of urban areas (DeGraaf and Wentworth, 1986; Geis, 1974). Several studies indicated that development and land use activities may actually impact the forest habitats adjacent to them. The bird communities were particularly affected by adjacent land use practices (Tilghman, 1987, Dowd, 1992, Smith and Schaefer, 1992).

Dowd (1992) suggested that urban development can degrade the forest habitat, leading to a bird community resembling that of the adjacent urban environment. Smith and Schaefer (1992) identified adjacent land use as a factor responsible for avian community differences between forested sites adjacent to rural and urban areas.

Tilghman (1987) also examined the effects of urban development on forest bird communities. She found that the size of the woodland was the most important variable in explaining differences in the number of species and species diversity, with larger areas supporting more species with greater diversity.

The literature also suggested that adjacent land use practices may impact the mammalian communities of urban habitats (VanDruff and Rowse, 1986; Nilon and VanDruff, 1987; Matthiae and Stearns, 1981). A component of the mammalian community that may indirectly affect the avian community is nest predators.

Best and Stauffer (1980) described factors affecting nesting success in riparian bird communities. They determined that the causes of nest failure, in order of decreasing importance, were predation, desertion, cowbird parasitism, and natural disasters.

In general, predation rates are often higher in small forest fragments than in larger ones and higher near edge in forested areas than in the interior (Wilcove, 1985; Small and Hunter, 1988; Yahner and Scott, 1988). The brown-headed cowbird, a nest parasite, is also more abundant along forest edge than interior and parasitism rates are usually higher near forest edges (Brittingham and Temple, 1983; Robinson et al., 1993). With small forest size and high amounts of edge, the refuge floodplain forest bird communities may be vulnerable to predation and parasitism.

In addition, higher nest predation has been documented in woodlots adjacent to developed areas. Using artificial nests, Wilcove (1985) found that nest predation rates were 70.5% in woodlots near suburban neighborhoods compared to 47.5% for woodlots in isolated, rural areas. He also suggested that dogs (Canis familiaris), cats (Felix cattus), and rats (Rattus spp.) from the adjacent areas probably add to the predator base in urban environments. Soule et. al. (1988) also suggested that development of areas adjacent to chaparral habitat resulted in an increase in a number of mammalian predators.

Habitat structural change was another consequence of adjacent land use activity. Hobbs' (1988) study of urban forest islands in St. Paul, Minnesota indicated that floodplain forests were vulnerable to changes associated with urban development. She documented changes in tree species composition and vegetation structure of floodplain forest remnants adjacent to urban development, noting a shift in species composition to more xeric tree species. Hobbs suggested that succession from wet to mesic conditions had occurred as a result of the adjacent urbanization. Another factor she noted as changing the forest composition and structure was the establishment of an exotic shrub, European buckthorn (Rhamnus frangula). These structural alterations could conceivably lead to changes in the faunal communities of these forests.

These studies indicate that development and land use activities may have impacts upon the wildlife communities of adjacent habitats. There may be changes in the bird community, changes in habitat structure, and potentially, an increase in predation and parasitism due to activities in the adjacent areas.

Minnesota Valley provides a unique opportunity to study the impacts of adjacent land use on bird communities. The linear floodplain forest habitats, extending along the Minnesota River from the near inner city area of the Minneapolis International Airport to the rural and agricultural area of Jordan, Minnesota, are bordered by various land use types. With an understanding of the potential impacts of adjacent land use, attempts could be made to buffer and better protect the refuge habitats. Consequently, this project was initiated to determine some of the impacts of adjacent land use on floodplain forest bird communities at Minnesota Valley National Wildlife Refuge.

Two questions guided the research of the breeding bird study:

1) Are there differences in the breeding bird communities of the floodplain forests adjacent to commercial/service, industrial, residential, and agricultural land uses?

2) Do the floodplain forests support a breeding bird community that is distinct from the adjacent land use areas?

To help answer this question, I posed the following hypotheses:

1) H_o: There is no difference in total bird density, seed eating omnivore density, insectivore, introduced species density, native species density, neotropical migrant species density, and nest predator/parasite density among the four floodplain forest stands adjacent to commercial/service, industrial, residential, and agricultural land uses.

2) H_o: There is no difference in mean avian richness among the floodplain forest stands adjacent to the various land uses.

Study area

The study areas were the same as described in chapter one.

Methods

Breeding bird counts

Breeding bird counts were conducted on each site from 28 May to 30 June 1992 and 27 May to 20 June 1993 using the plot mapping technique (Christman, 1984; Emlen, 1977). Each transect was walked 20 times during the breeding season from sunrise to 0900 hrs and all birds seen or heard during an eight minute period were counted. Windy or rainy days were avoided for censusing. The two field observers had a college ornithology course and were trained in the data recording procedures.

Mammal counts

Abundance of mammalian predators was monitored from 2 June to 12 July 1992 using scent post surveys (Linhart and Knowlton, 1975). The 1993 surveys could not be conducted due to rain frequency and flood waters. For each station, a 1 m diameter circle was cleared of all debris and sand was sifted evenly over the area. A q-tip swab dipped in a synthetic fatty acid attractant was placed in the center of the cleared circle. The previous night's weather conditions were recorded and all tracks within the station were identified.

Three 1 km transects with five scent post stations, one every 200 m, were run at each site. One transect was run in the area adjacent to the floodplain forest (Outer). One was run at the interface of the forest and the adjacent area (Edge). One was run in the interior of the floodplain forest (Inner). Each site was surveyed three times, with a survey consisting of three consecutive nights of scent post monitoring.

Vegetative sampling

Vegetation measurements were taken at each transect. Habitat variables measured were: canopy height, percent canopy cover, percent ground cover, trees per ha (over 7.6 cm dbh), basal area, and shrub stems per ha. Five 0.04 ha circular plots were measured along each transect according to the methods described by James and Shugart (1970). Circular plots were placed on alternating sides of the bird transects every 20 m. The plots were 16.7 m from the transect center at right angles.

Principal components analysis (PCA) (Wilkinson, 1990) was used as a data selection procedure for the vegetative data (Table 3.1). Canopy cover (CC), grass cover (GR), artificial cover (AF), shrub density (SD), and basal area (BA) were chosen based on the PCA and their biological significance to the avian species as environmental variables for detrended canonical correspondence analysis (ter Braak, 1986).

Statistical analysis

Two techniques were used to analyze the breeding bird data, ordination and nonparametric analysis of variance (ANOVA).

Ordination (ter Braak and Prentice, 1988) was used to analyze the spatial pattern of the bird communities at the floodplain forest and adjacent land use sites. This technique allowed me to

Table 3.1. Eigenvalue and principle component loadings for the habitat variables for the floodplain forest and adjacent land use sites at the Minnesota Valley National Wildlife Refuge.

Component	Principle component loadings	
	Principle Component 1	Principle 2
Eigenvalue	7.62	2.80
Canopy cover	0.93	0.25
Canopy height	0.88	0.18
Leaf litter	0.74	0.33
Woody litter	0.73	0.50
Grass	-0.25	-0.86
Bare soil	-0.54	-0.75
Rock	-0.89	0.32
Forb	0.69	-0.49
Artificial	-0.88	0.31
Water	-0.63	0.67
Shrub density	0.75	0.07
Basal area	0.92	0.35
Tree density	0.84	0.17

group sites based on their species composition and abundance and to identify the environmental gradients underlying this pattern. The 1992 and 1993 avian data sets were combined and detrended correspondence analysis (DCA) (ter Braak, 1987) was used to identify the species explaining most of the variation within the avian community. Species were selected with weights > 0.2 and first axis species scores > 2.0 or < -0.5. Comparisons of the mean avian density for these species were then made among the sites on rank transformed data with ANOVA procedures using the SAS statistical package (SAS Institute Inc, 1985). Fisher's protected least significant differences multiple comparisons (LSD's) were used to compare means.

Canonical correspondence analysis (CCA) (ter Braak, 1987) was used to correlate the habitat variables to the ordination axes. This allowed me to identify the habitat features associated with the ordination gradients.

The bird species were grouped based on life history characteristics and compared with ANOVA. All the individual species were pooled to form a total bird mean (TOTBD) density. The avian species were also grouped based on their foraging guilds: seed-eaters/omnivores (SDOMNI) and insectivores (INSECT) (DeGraaf and Wentworth, 1986); and whether they were introduced (INTRO) or native (NATV) species. Literature suggested that introduced species may spill over from the adjacent areas and that there would be more seed-eaters/omnivores and less insectivores if there was a land use effect (DeGraaf and Wentworth, 1986; Tilghman, 1987; Smith and Schaefer, 1992). I also grouped species that were neotropical migrants (NEO) (Finch, 1991) and nest predators or parasites (NPP) (Martin and Roper, 1988; Small and Hunter, 1988; Wilcove, 1985; Brittingham and Temple, 1983). Literature suggested that migrants would be negatively affected by adjacent land use and nest predator/parasites would possibly increase (Askins, et al., 1990; Finch, 1991).

Results

Summer 1992 avian data

Forty-eight species were detected in the floodplain forests and adjacent land use sites with 2092 total detections (Appendix D). The floodplain forests supported 38 species, 19 of which were not detected in the adjacent areas (Appendix E). Twenty-nine species were detected in the areas adjacent to the floodplain forest (Appendix F). Comparing the floodplain forest bird community, TOTBD density was different ($F=18.87$, $P=0.0001$, $df=6$) among the floodplain forest sites. INI had a higher ($P < 0.05$) mean density than the three other sites (Table 3.2). NATV density was also different ($F=19.31$, $P=0.0001$, $df=6$) among the forested sites, with INI having higher ($P < 0.05$) mean density (Table 3.2). There was no difference in INTRO density. There were differences ($F=11.24$, $P=0.0001$, $df=6$) in INSECT density among the floodplain forest sites. INI had higher ($P < 0.05$) mean density of insectivores. SDOMNI density was different ($F=12.16$, $P=0.0001$, $df=6$) among the floodplain forest sites. AGI and INI had higher ($P < 0.05$) mean densities than RSI and CSI. NEO density was also different ($F=23.55$, $P=0.0001$, $df=6$) among the forested sites, with INI again having the highest ($P < 0.05$) mean density. There was no difference in nest predator/parasite densities among the sites. Mean species richness did not differ among the floodplain forest sites (Tables 3.2).

I pooled the floodplain forest sites and the adjacent land use areas to compare the mean avian density between these sites. Differences in mean avian density for TOTBD ($F=7.32$, $P=0.0073$, $df=1$), INTRO ($F=392.61$, $P=0.0001$, $df=1$), NATV ($F=242.27$, $P=0.0001$, $df=1$), INSECT ($F=664.66$, $P=0.0001$, $df=1$), NEO ($F=204.55$, $P=0.0001$, $df=1$), and NPP ($F=13.88$, $P=0.0002$, $df=1$) were observed (Table 3.3). The floodplain forest stands had higher ($P < 0.05$) mean densities for TOTBD, NATV, INSECT, and NEO. The adjacent sites had higher ($P < 0.05$) densities of INTRO and NPP.

When the forested sites were pooled and mean avian richness compared with the pooled adjacent sites, a difference ($F=32.11$, $P=0.0001$, $df=1$) was detected. The floodplain forest sites had a mean richness of 16.7 species/transect. This was higher ($P < 0.05$) than the 10.0 species/transect observed at the adjacent land use sites.

Comparing the bird communities among the adjacent land use sites, TOTBD ($F=18.87$, $P=0.0001$, $df=6$), INTRO ($F=47.48$, $P=0.0001$,

Table 3.2. Mean density (birds/ha) of avian life history grouping and species richness at the floodplain forest sites on the Minnesota Valley National Wildlife Refuge during the breeding season, 1992.

	Sites			
Life history Groupings	RSI	CSI	AGI	INI
TOTBD*	7.25b	7.00b	7.12b	11.33a
INTRO	0	0	0.03	0.06
NATV*	7.25b	7.00b	7.09b	11.28a
INSECT*	4.78b	5.31b	3.61c	7.94a
SDOMNI*	2.08b	1.50b	3.30a	3.28a
NEO*	4.78c	5.36b	4.61bc	8.81a
NPP	0.33	0.19	0.30	0.14
Mean Species Richness	15.7	16.0	17.3	17.7
Total Richness	22	23	25	26

*Differences among sites (P < 0.05)

Values with different letters are significantly (P <0.05) different

Table 3.3. Mean avian density for life history groupings at the floodplain forest and adjacent land use sites during the breeding season, 1992.

	Sites	
Species groupings	Floodplain forests	Adjacent land uses
TOTBD*	8.20	7.80
INTRO*	0.02	4.15
NATV*	8.18	3.65
INSECT*	5.45	0.73
SDOMNI*	2.52	6.83
NEO*	5.66	2.39
NPP*	0.24	0.72

*Differences among sites ($\underline{P} < 0.05$)

df=6), NATV ($F=19.31$, $P=0.0001$, df=6), INSECT ($F=11.24$, $P=0.0001$, df=6), SDOMNI ($F=12.16$, $P=0.0001$, df=6), and NEO ($F=23.55$, $P=0.0001$, df=6), showed differences among the sites (Table 3.4). TOTBD, SDOMNI, and INTRO had higher ($P < 0.05$) mean density at INO. NATV, INSECT, and NEO had higher ($P < 0.05$) mean density at AGO.

Ordination identified ten species that may be important to explaining the variation in the avian community data. Differences ($P < 0.05$) in mean density were observed for eight of these species in 1992, four of which were higher ($P < 0.05$) at INI (Table 3.5).

Summer 1993 avian data

Fifty-four species were detected at the floodplain forest and adjacent land use sites with 1809 total detections (Appendix G). The floodplain forests supported 38 species, 16 of which were not detected in the adjacent areas (Appendix H). Thirty-eight species were also detected in the areas adjacent to the floodplain forest, 16 of which were unique to these adjacent land use areas (Appendix I).

Comparing the floodplain forest bird communities, TOTBD ($F=22.96$, $P=0.0001$, df=6), INTRO ($F=60.86$, $P=0.0001$, df=6), NATV ($F=11.48$, $P=0.0001$, df=6), INSECT ($F=13.45$, $P=0.0001$, df=6), SDOMNI ($F=12.37$, $P=0.0001$, df=6), and NEO ($F=27.07$, $P=0.0001$, df=6) showed differences (Table 3.6). Higher ($P < 0.05$) densities of TOTED, NATV, INSECT, and NEO were observed at INI. RSI, AGI, and INI had higher ($P < 0.05$) density of SDOMNI than CSI, while AGI had a higher ($P < 0.05$) density of INTRO than the other sites. There was

Table 3.4. Mean density (birds/ha) of the avian life history grouping and species richness at the adjacent land use sites for the breeding season, 1992.

Life history groupings	Sites			
	RSO	CSO	AGO	INO
TOTBD*	5.33c	5.53bc	7.30b	13.03a
INTRO*	2.17b	2.73bc	0.17d	11.53a
NATV*	3.17b	2.80bc	7.13a	1.50d
INSECT*	0.73ab	0.47b	1.13a	0.57b
SDOMNI*	4.37b	S.OOb	5.57b	12.40a
NEO*	1.97b	1.83bc	5.13a	0.63d
NPP	0.63	0.90	0.93	0.40
Mean Species Richness	10.3	10.7	12.0	7.0
Total Richness	18	15	20	13

*Differences among sites ($\underline{P} < 0.05$)

Values with different letters are significantly ($\underline{P} < 0.05$) different

Table 3.5. Mean avian density (birds/ha) of the species identified via ordination for the floodplain forest sites during the breeding season, 1992.

	Sites			
Species	RSI	CSI	AGI	INI
COYE*	0.36b	0.25bc	0.82a	0.06d
GCFL*	0.67a	0.39b	0.33bc	0.08d
GRCA*	0.06b	0.08b	0.09b	0.36a
HAWO	0.11	0	0.03	0.03
LEFL*	Ob	0.08b	0.03b	1.33a
RHWO*	Ob	Ob	0.42a	Ob
WAVI*	Ob	0.08b	Ob	0.42a
WODU	0	0	0.03	0
YEWA*	Ob	Ob	Ob	2.19a

* Differences among sites (P < 0.05)

Values with different letters are significantly (P <0.05) different a difference (F=4.31, P=0.044, df=3) among the floodplain forest stands in mean species richness (Table 3.6).

hen the floodplain forest sites were pooled and then compared to the adjacent land use sites, differences were detected in TOTED (F=33.68, P=0.0001, df=1), INTRO (F=333.89, P=0.0001, df=1), NATV (F=304.79, P=0.0001, df=1), INSECT (F=549.24, P=0.0001, df=1), SDOMNI (F=75.32, P=0.0001, df=1), NEO (F=400.74, P=0.0001, df=1), and NPP (F=8.02, P=0.0001, df=1) density between sites (Table 3.7). Higher (P < 0.05) mean densities of TOTED, NATV, INSECT, and NEO were observed at the floodplain forest sites. INTRO, SDOMNI and NPP densities were higher (P < 0.05) at the adjacent land use sites.

When the forest and adjacent sites were pooled, there was a difference (F=30.64, P=0.0001, df=1) in mean species richness. The floodplain forest sites had a higher (P < 0.05) mean species richness, 17.6 species/transect, than the adjacent land use sites, 10.8 species/transect.

Comparing bird communities of the adjacent land use sites, differences were detected for TOTBD (F=22.96, P=0.0001, df=6), INTRO (F=60.86, P=0.0001 df=6), NATV (F=11.48, P=0.0001, df=6), INSECT (F=13.45, P=0.0001, df =6), SDOMNI (F=12.37, P=0.0001, df=6), and NEO (F=27.07, P=0.0001, df=6) densities (Table 3.8). TOTBD, INTRO, and SDOMNI had higher (P < 0.05) densities at INO. AGO had higher (P < 0.05) densities of NATV, while AGO and INO supported higher (P < 0.05) densities of INSECT than CSO. NEO densities were higher (P < 0.05) at AGO and RSO than CSO and INO.

Table 3.6. Mean density (birds/ha) of avian life history groupings and species richness at the floodplain forest sites during the breeding season, 1993.

	Sites			
Life history groupings	RSI	CSI	AGI	INI
TOTBD*	4.90c	5.90b	5.64bc	7.79a
INTRO*	0b	0b	0.21a	0b
NATV*	4.90c	5.90b	5.44bc	7.79a
INSECT*	2.92d	4.69b	3.79c	5.81a
SDOMNI*	1.97a	1.21b	1.85a	1.95a
NEO*	2.67d	4.67b	3.59c	6.71a
NPP	0.28	0.02	0.13	0.14
Mean Species Richness*	17.0ac	17.3ab	19.3a	16.7bc
Total Richness	22	23	27	23

*Differences among sites ($P < 0.05$)

Values with different letters are significantly ($P < 0.05$) different

Table 3.7. Mean avian density (birds/ha) for the life history groupings at the floodplain forest and adjacent land use sites during the breeding season, 1993.

Life history groupings	Sites: Floodplain forests	Sites: Adjacent land uses
TOTBD*	6.09	5.08
INTRO*	0.05	2.42
NATV*	6.04	2.66
INSECT*	4.34	1.02
SDOMNI*	1.74	4.05
NEO*	4.46	1.39
NPP*	0.14	0.32

*Differences among sites ($\underline{P} < 0.05$)

Mean species richness did not differ among the adjacent land use sites (Table 3.8) Ordination identified eight species that may be important explaining the variation in the floodplain forest avian community data set. Differences ($P < 0.05$) in mean density were observed for seven of these species in 1993, four of which were higher ($\underline{P} < 0.05$) at INI (Table 3.9).

Vegetative measurements

The vegetative structure of the floodplain forest was distinct from that of the adjacent land use areas (Tables 3.10 and 3.11). Differences were observed in the structure of the floodplain forest for tree and shrub density ($F=67.72$, $\underline{P}=0.0001$, $df=3$ and $F=134.71$, $\underline{P}=0.0001$, $df=3$), leaf litter ($F=52.27$, $\underline{P}=0.0001$, $df=3$), woody litter ($F=53.07$, $\underline{P}=0.0001$, $df=3$), and grass and forb cover ($F=10.35$, $\underline{P}=0.001$, $df=3$ and $F=7.91$, $\underline{P}=0.004$, $df=3$).INI had higher ($\underline{P} < 0.05$) tree and shrub density. The understory of INI had higher ($\underline{P} < 0.05$) forb and grass cover and lower ($\underline{P} < 0.05$) leaf and woody ground cover (Table 3.10). The species

Table 3.8. Mean density (birds/ha) of avian life history grouping and species richness at the adjacent land use sites during the breeding season, 1993.

	Sites			
Life history groupings	RSO	CSO	AGO	INO
TOTBD*	4.97b	3.14c	3.85c	8.26a
INTRO*	2.26b	1.29c	0.03d	5.93a
NATV*	2.72b	1.86c	3.82a	2.33bc
INSECT*	0.97ab	0.57b	1.31a	1.23a
SDOMNI*	4.00b	2.57c	2.48c	7.02a
NEO*	1.90ab	1.31c	2.00a	0.43d
NPP	0.54	0.24	0.23	0.29
Mean Species Richness	12.7	10.7	8.7	11.0
Total Richness	24	18	21	14

*Differences among sites ($P < 0.05$)

Values with different letters are significantly ($\underline{P} < 0.05$) different

Table 3.9. Mean avian density (birds/ha) of the species identified via ordination for the floodplain forest sites during the breeding season, 1993.

	Sites			
Species	RSI	CSI	AGI	INI
BLJA*	0.21a	Ob	O.10ab	Ob
GCFL*	0.64a	0.31b	0.31b	Oc
GRCA*	Ob	Ob	Ob	0.17a
HAWO	0.18	0.10	0.23	0.07
LEFL*	Ob	Ob	0.05b	0.74a
WAVI*	Ob	0.02b	0.03b	0.50a
WODU*	0.26a	O.1Ob	0.03b	Ob
YEWA*	Ob	Ob	Ob	0.95a

* Differences among sites ($P < 0.05$)

Values with different letters are significantly ($P < 0.05$) different

Table 3.10. Mean vegetative structure values of the floodplain forest sites on the Minnesota Valley National Wildlife Refuge.

	Sites			
	RSI	CSI	AGI	INI
Canopy cover (%)	86.7	86.0	77.7	78.6
Canopy height (m)	24.3	26.2	28.7	22.4
Ground cover (o)				
Leaf litter*	36.7a	33.7a	9.0b	6.3b
Woody litter*	25.7a	13.7b	11.0b	2.3c
Grass*	8.3bc	4.0c	44.7a	31.7ab
Bare soil	8.7	2.3	12.0	0.7
Rock	0	0	0	0.3
Forb*	20.7b	46.3ab	23.3b	58.7a
Basal area (m2/ha)	40.5	32.2	25.8	25.0
Tree density* (trees/ha)	509b	404b	135c	706a
Shrub density* (stems/ha)	1500c	2833b	167d	5000a

*Differences among sites ($\underline{P} < 0.05$)

Values with different letters are significantly ($\underline{P} < 0.05$) different

Table 3.11. Mean vegetative structure values of the adjacent land use sites on the Minnesota Valley National Wildlife Refuge.

	Sites			
Vegetative measure	RSO	CSO	AGO	INO
Canopy cover (%)	3.3	11.7	0	0
Canopy height (m)	1.7	8.0	0	0
Ground cover (%)				
Leaf litter	2.7	3.0	16.2	1.3
Grass	43.6	38.0	45.0	7.0
Bare soil	4.7	1.7	3.0	30.1
Rock	5.7	4.3	0.3	9.2
Forb	14.7	30.0	35.5	3.3
Artificial	28.7	23.0	0	44.5
Water	0	0	0	4.7
Basal area (m2/ha)	1.3	1.5	0	0
Tree density (trees/ha)	5.3	4	0	0
Shrub density (stems/ha)	25	20	10	0

composition of the forest at INI was also different from the other sites (Table 3.12). The black willow was a dominant species at INI, while no silver maples were detected.

The 1992 and 1993 avian community data for the floodplain forest and adjacent land use sites were combined and ordinated with the environmental variables. The avian species were separated into a group with negative scores, that used forest habitats, and positive scores, that use open or built habitats (Table 3.13 and Figure 3.1). This is also demonstrated in the ordination of the sites, with the floodplain forest sites being clustered on the left and the adjacent land use sites on the right (Figure 3.2). The first two ordination axes explained 740 of the variation in the species-environmental data relationship. The first axis had positive scores for artificial ground cover and negative scores for canopy cover, basal area, and shrub density. This axis can be defined in terms of a developmental gradient (i.e. from wooded to built areas). The second axis had a positive score for grass cover and negative scores for canopy cover, basal area, and shrub density (Table 3.13). The second axis can be defined in terms of a forested to grass gradient.

The 1992 and 1993 avian community data sets for the floodplain sites were combined and ordinated with basal area, shrub density, and grass cover. The avian species were separated along the first axis on a shrub to forest gradient (Figure 3.3). The avian species with positive scores generally selected for

Table 3.12. Basal area and tree density by species for the floodplain forest stands of the Minnesota Valley National Wildlife Refuge.

	Sites			
	RSI	CSI	AGI	INI
Basal area (m^2/ha)	40.5	32.2	25.8	25.0
American elm	2.8	2.3	1.0	1.5
Box elder	0.8	1.6	0.3	3.1
Black willow	5.3	2.3	3.6	12.9
Cottonwood	6.5	8.7	1.3	7.0
Green ash	4.8	6.0	1.5	0.5
Silver Maple	20.3	11.3	18.1	0
Tree density (trees/ha)	509	404	135	706
American elm	86.5	141.4	36.5	91.8
Box elder	25.4	52.5	6.7	162.4
Black willow	50.9	32.3	4.1	282.4
Cottonwood	61.1	12.1	2.7	120.0
Green ash	66.2	92.9	17.5	49.4
Silver Maple	218.9	72.8	67.5	0

Table 3.13. Eigenvalue, percentage of variance explained, biplot scores, and weights for the detrended canonical correspondence analysis of the combined floodplain forest and adjacent land use bird and environmental data.

	Axes scores		
	Axis 1	Axis 2	Weight
Eigenvalue	0.77	0.59	---
Percentage of variance explained	37.3	28.4	---
AMCR	0.49	-0.21	0.32
AMGO	-0.08	0.36	1.52
AMKE	0.73	-0.20	0.01
AMRE	-0.83	-0.32	1.10
AMRO	-0.08	1.44	3.82
BAOW	-0.89	-0.19	0.03
BASW	1.21	-0.46	0.18
BAWW	-0.70	-3.52	0.04
BCCH	-0.68	-0.18	1.27
BGGN	-0.94	-0.42	0.30
BHCO	0.37	0.93	1.22
BLJA	-0.47	-0.15	0.65
BRCR	-0.87	-0.23	0.11
CEWA	-0.99	-0.56	0.05
CHSP	0.61	0.70	0.22
COGR	0.84	0.47	0.78
CONI	0.74	-0.21	0.01
COYE	-0.38	0.33	2.06
DICK	0.19	2.97	0.54
DOWO	-0.85	-0.23	0.92
EAKI	0.46	1.46	0.36
EAME	0.19	2.97	0.73
EAPH	0.74	-0.21	0.03

Table 3.13. Continued.

EUST	1.03	-0.16	2.14
EWPE	-0.84	-0.25	1.03
GCFL	-0.80	-0.17	0.38
GRCA	-0.91	-0.40	0.31
GRSP	0.19	2.97	0.22
HAWO	-0.78	-0.20	0.38
HETH	-0.87	-0.23	0.01
HOFI	1.21	-0.22	0.07
HOSP	1.32	-0.44	10.86
HOWR	-0.74	-0.28	7.02
INBU	0.28	0.41	0.17
KILL	1.54	-0.63	0.81
LEFL	-0.97	-0.53	1.18
MALL	1.59	-0.67	0.07
MODO	0.47	1.43	0.46
NOCA	-0.60	-0.30	0.80
NOFL	-0.90	-0.20	0.02
NOOR	-0.89	-0.39	0.55
PIWO	-0.89	-0.19	0.01
POWA	-0.87	-0.23	0.02
RBGR	-0.87	-0.34	0.31
RBWO	-0.65	0.21	0.18
REVI	-0.85	-0.23	1.11
RHWO	-0.66	-0.08	0.21
RNPH	0.19	2.97	0.04
RODO	1.58	-0.67	0.04
RWBL	0.21	2.55	1.35
SCOW	-0.87	-0.23	0.01
SOSP	-0.59	0.36	2.23
SWTH	-0.87	-0.23	0.03
TRSW	-0.66	0.46	0.19
WAVI	-0.98	-0.52	0.48

Table 3.13. Continued.

WBNU	-0.76	-0.22	1.32
WODU	-0.86	-0.19	0.20
YEWA	-0.98	-0.55	1.59
Canopy cover	-0.93	-0.32	---
Grass cover	-0.11	0.48	---
Artificial cover	0.95	-0.31	---
Shrub density	-0.71	-0.30	---
Basal area	-0.89	-0.29	---

Figure 3.1. Ordination of the floodplain forest and adjacent land use Avian species using detrended canonical correspondence analysis.

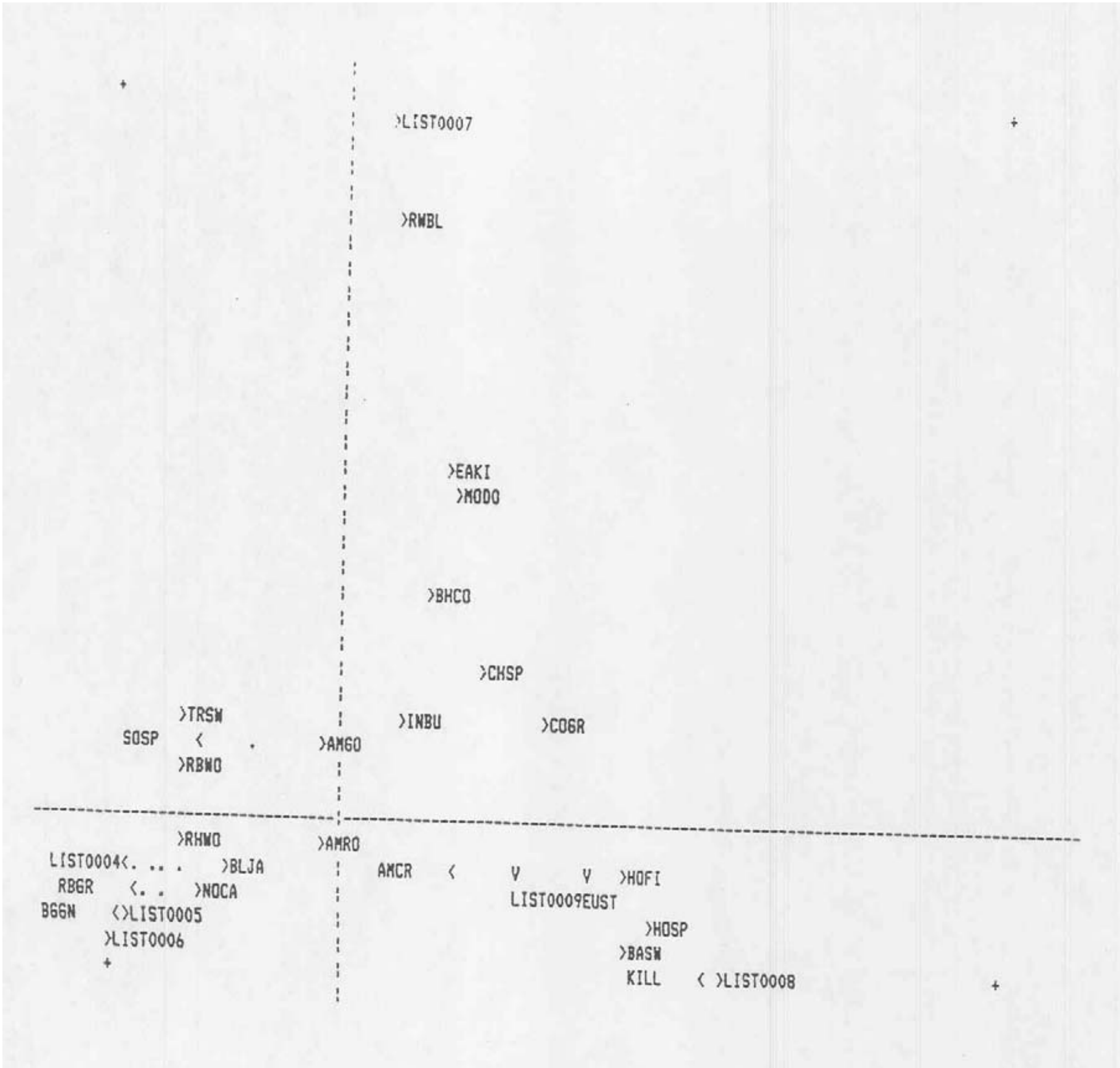
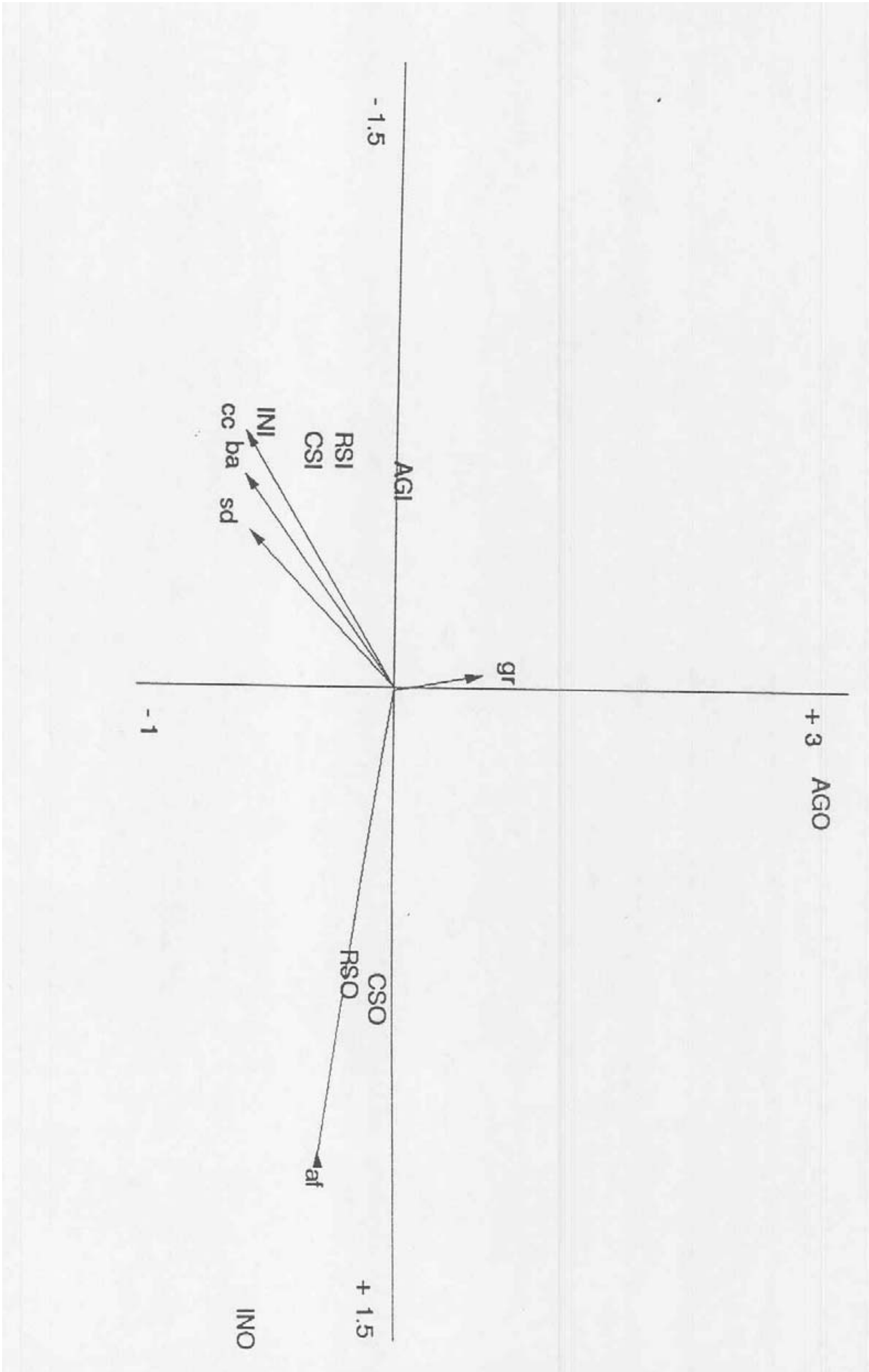

>LIST0007
>RWBL
>EAKI
>MODO
>BHCO
>CHSP
>TRSW
>INBU
>COGR
SOSP <
>AMGO
>RBWO
>RHWO
>AMRO
LIST0004<. .. . >BLJA
AMCR < V V >HOFI
RBGR <. . >NOCA
LIST0009EUST
BGGN <>LIST0005
>LIST0006
>HOSP
>BASW
KILL < >LIST0008

Figure 3.2. Ordination of the floodplain forest and adjacent land use sites using detrended canonical correspondence analysis.


- 1.5
AGI
RSI
CSI
INI
cc
ba
sd
gr
- 1
+ 3
AGO
CSO
RSO
af
+ 1.5
INO

Scent post surveys

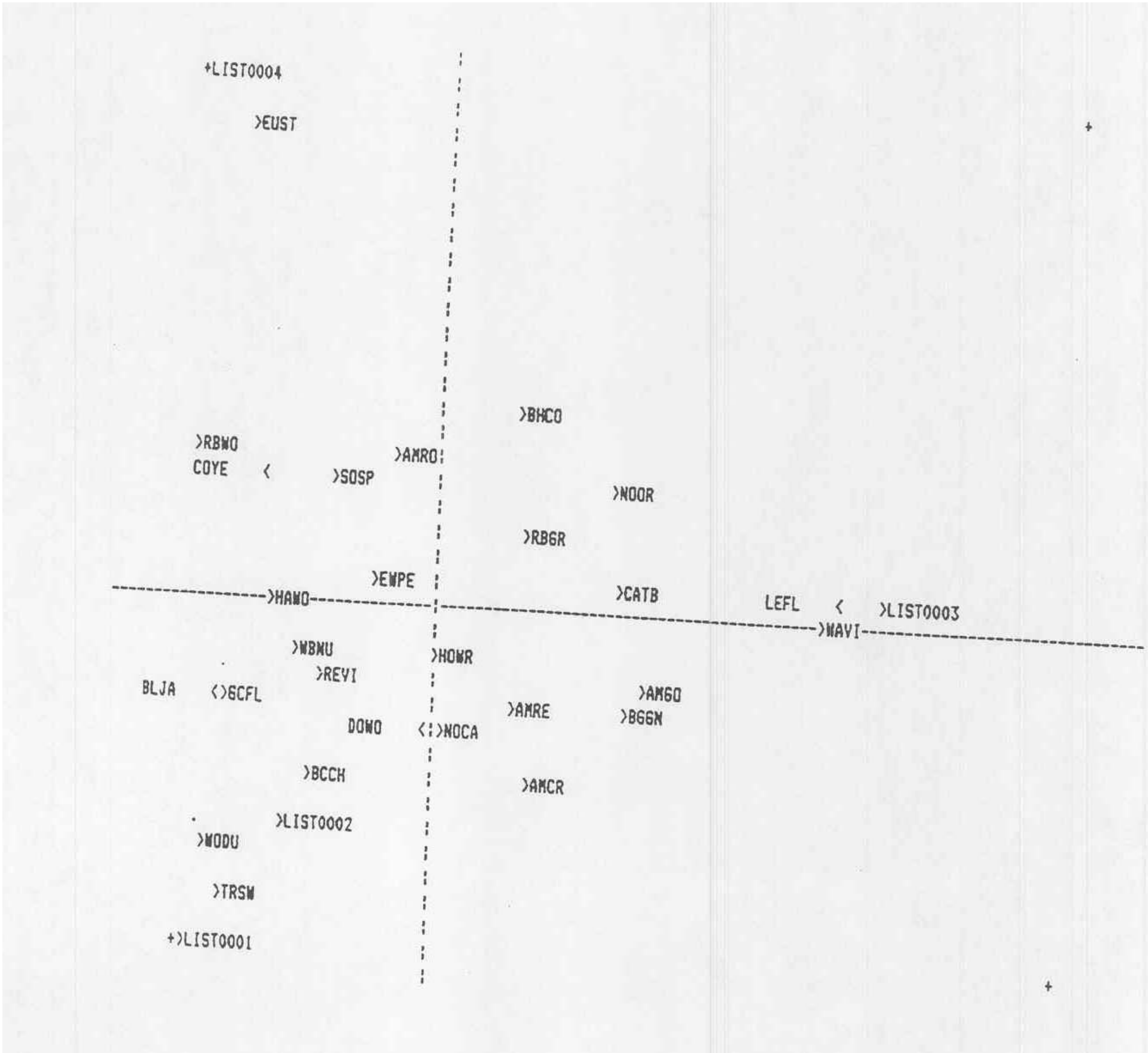
Eleven mammalian species were detected with the scent post surveys (Table 3.15). The potential predators and nest predators had more numerous detections in the edge and outer areas than in the forest itself (Table 3.16).

Discussion

Two questions guided the research of the breeding bird section of this study. The first question was are there differences in the floodplain forest bird communities based on the type of adjacent land use practice? There were differences in TOTBD, NATV, INSECT, and NEO density among the floodplain forests adjacent to the four land use types. The floodplain forest adjacent to industrial land use had higher TOTED, NATV, INSECT, and NEO densities than all the other sites in 1992 and 1993. There was no difference in mean species richness among the sites in 1992. In 1993, the forest adjacent to industrial land use had a lower mean richness than the forest adjacent to agricultural land use.

CCA of the floodplain forest bird community with the environmental variables indicated that shrub density may be a factor explaining the difference in species composition. Shrub density was one of the vegetative differences observed among the forested sites. INI had a denser, shrubby component to the forest than the other sites.

Figure 3.3. Ordination of the floodplain forest avian species using detrended canonical correspondence analysis.



LIST0004
EUST
BHCO
RBWO
COYE
AMRO
SOSP
NOOR
RBGR
EWPE
HAWO
CATB
LEFL
LIST0003
WAVI
WBNU
HOWR
REVI
BLJA
GCFL
AMGO
AMRE
BGGN
DOWO
NOCA
BCCH
AMCR
LIST0002
WODU
TRSW
LIST0001

Table 3.14. Eigenvalue, percentage of variance explained, biplot scores, and weights for the detrended canonical correspondence analysis of the combined floodplain forest bird and environmental data.

	Axes scores		
	Axis 1	Axis 2	Weight
Eigenvalue	0.35	0.15	---
Percentage of Variance explained	56.8	24.7	---
AMCR	0.30	-0.52	0.06
AMGO	0.66	-0.23	0.66
AMRE	0.23	-0.29	1.05
AMRO	-0.15	0.53	2.11
BAOW	-0.80	-1.12	0.03
BAWW	-0.48	-0.70	0.04
BCCH	-0.41	-0.51	1.11
BGGN	0.59	-0.25	0.30
BHCO	0.25	0.64	0.17
BLJA	-0.71	-0.30	0.49
BRCR	-0.48	-0.70	0.11
CEWA	1.40	0.09	0.05
COGR	1.40	0.09	0.01
COYE	-0.56	0.43	1.43
DOWO	-0.04	-0.34	0.89
EUST	-0.66	1.54	0.12
EWPE	-0.22	0.13	1.03
GCFL	-0.68	-0.32	1.35
GRCA	1.40	0.09	0.31
HAWO	-0.53	0.04	0.37
HETH	-0.48	-0.70	0.01
HOSP	1.40	0.09	0.01

<PAGE 75 MISSING FROM HARD COPY>

Figure 3.4. Ordination of the floodplain forest sites using detrended canonical correspondence analysis.

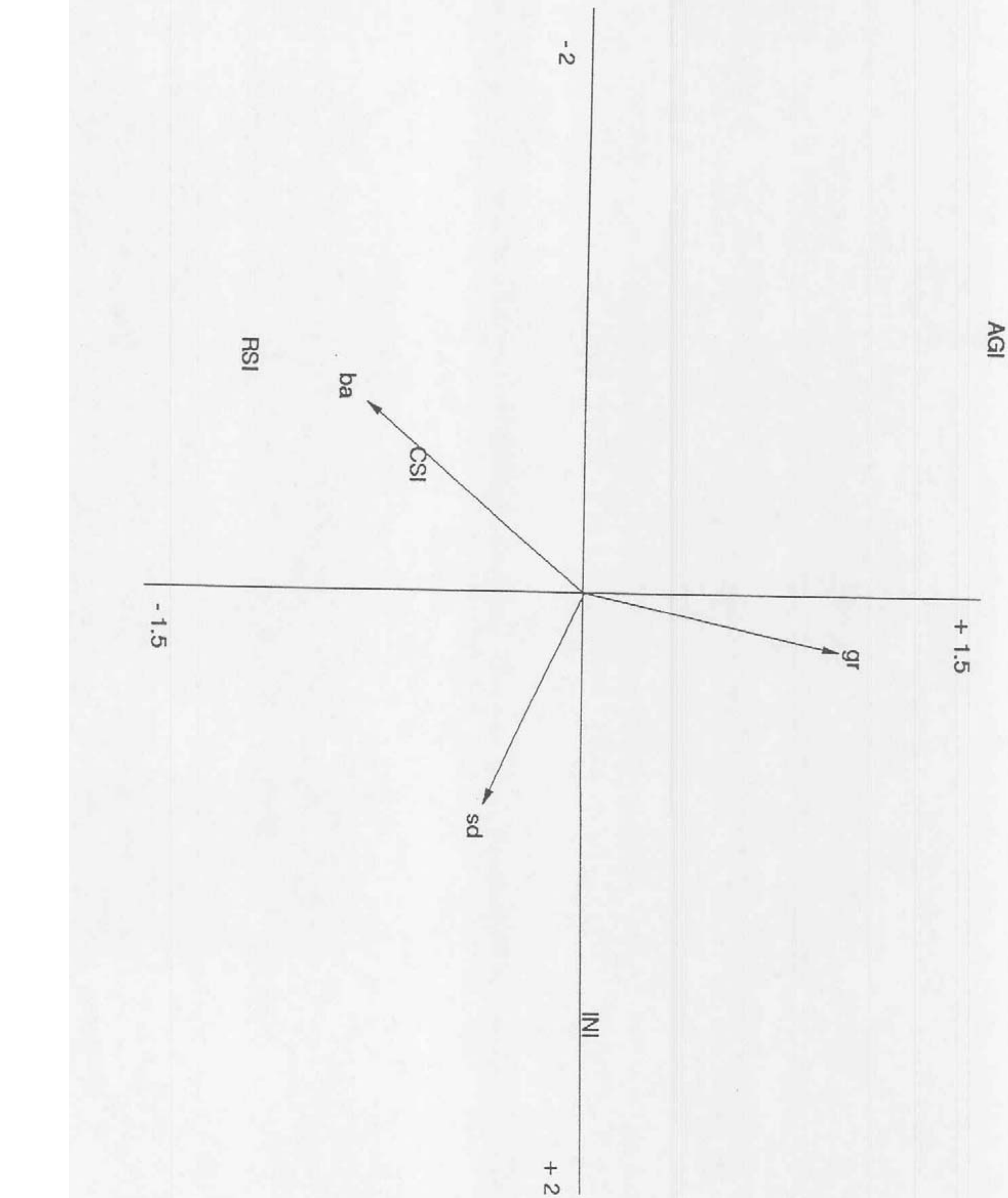

AGI
RSI
ba
CSI
- 2
+ 1.5
gr
- 1.5
sd
INI
+ 2

Table 3.15. Number of mammalian scent post station detections per site at the Minnesota Valley National Wildlife Refuge.

		HQ			BF			LV			PC	
SPECIES	EDGE	INNER	OUTER	EDGE	INNER	OUTER	EDGE	INNER	OUTER	EDGE	INNER	OUTER
Beaver	0	0	0	0	0	0	5	0	0	0	0	0
Cat	0	0	0	0	2	6	0	0	1	0	0	0
Deer	11	23	1	18	15	0	8	9	5	5	28	17
Dog	3	0	7	4	7	20	0	4	21	0	1	0
Muskrat	0	0	0	0	0	0	9	0	0	1	0	0
Rabbit	3	0	2	0	0	0	0	3	0	0	0	2
Raccoon	9	11	2	2	7	5	14	5	3	6	5	11
Redfox	1	0	0	0	0	0	0	2	4	0	0	0
Skunk	3	0	0	6	1	0	0	0	0	0	0	2
Squirrel spp.	2	0	0	0	0	0	0	1	4	1	1	5
Woodchuck	4	0	0	0	0	0	0	0	0	18	0	17
Total visits	36	34	12	30	32	31	36	24	38	31	35	54

Note: See Appendix 2 for scientific names

<PAGE 79 MISSING FROM HARD COPY>

Differences in the vegetation structure probably accounted for the some of the differences observed in the avian community. A study in similar floodplain forest habitats (Swift et al., 1984) determined that total bird density and bird species richness was positively correlated with shrub density.

Four species had a higher mean density at INI than the other floodplain forest sites in 1992 and 1993, the yellow warbler, warbling vireo, least flycatcher, and gray catbird. These species were identified as important in explaining the variation within the floodplain forest bird community (via ordination). These species did not occur or had low mean density (< 0.10 birds/ha) at the other floodplain forest sites (CSI, RSI, AGI). These four species prefer shrubby breeding habitats (Bent, 1950abcd).

The adjacent land use may account for the vegetative differences and thus the differences in the bird communities of the floodplain forest. INI was located on land that is owned by the Cargill Corporation. At Port Cargill, barges are used as a means of grain distribution. They have a barge slip adjacent to the forest with a small levee that probably alters the flooding regime of this forest. Flooding of the riparian forest is important for ecosystem maintenance. The flood water and subsequent ground water levels are the main determinants of the vegetation type and productivity of floodplain forests (hitch and Gosselink, 1986; Lugo et al., 1990).

Consequently, the floodplain forest adjacent to industrial land use probably does not flood as frequently as the other forests. Change in the flooding frequency has been related to bird species density and diversity in other studies. Swift et al. (1984) found that water level fluctuation was the habitat variable most correlated with total bird density, bird species richness, and foliage gleaning birds for floodplain forests in Massachusetts. Hobbs' (1988) also noted that floodplain forests she studied in St. Paul, Minnesota, had shifted to more xeric species and suggested that succession from wet to mesic conditions had accompanied the urbanization of these lowland forests.

One final aspect of adjacent land use that may impact the bird communities was its influence on predators and nest predators. No difference was observed in avian nest predator/parasite density among the floodplain forest stands. The floodplain forest adjacent to industrial land use had fewer potential mammalian predators and nest predator detections than the other sites. Due to the nature of the scent post data, I could not test for differences. The forests adjacent to the residential (RSI) and agricultural (AGI) land use had more numerous predator and nest predator detections. Dogs and cats made up 84% and 67% of the predator and nest predator detections respectively in the adjacent (OUTER) residential and agricultural areas. Wilcove (1985) suggested that dogs, cats, and rats from the adjacent areas probably add to the predator base of woodlots in urban areas.

The second question guiding my research was do the floodplain forests support a bird community that is distinct from the adjacent land use areas? Ordination identified a forest to urban gradient that affected the avian species. The floodplain forest sites were separated from the adjacent land use sites along an axis defined by avian density, indicating that the forests and adjacent areas had distinct bird communities.

The floodplain forest sites had higher ($\underline{P} < 0.05$) TOTBD, NATV, INSECT, and NEO densities than the adjacent land use sites. This also suggested that their bird communities were distinct. These forested stands had a

<PAGE 83 MISSING FROM HARD COPY>

LITERATURE CITED

Ambuel, B. and Temple, S.A., 1983. Area-dependent changes in the bird communities and vegetation of Southern Wisconsin forests. Ecology, 64:1057-1068.

Angelstram, P., 1986. Predation on ground-nesting birds' nest in relation to predator densities and habitat edge. Oikos, 47:365-373.

Askins, R.A., Lynch, J.F., and Greenberg, R., 1990. Population declines in migratory birds in Eastern North America. In: D.M. Powers (Editor), Current ornithology, Vol. 7, Plenum Publishing Corp., New York, N.Y., pp. 1-57.

Bent, A.C., 1950a. Life histories of North American wagtails, shrikes, vireos., and their allies. U.S. Natl. Mus. Bull. 197. Washington, D.C.

Bent, A.C., 1950b. Life histories of North American nuthatches, wrens, thrashers, and their allies. U.S. Natl. Mus. Bull. 195. Washington, D.C.

Bent, A.C., 1950c. Life histories of North American flycatchers, larks, swallows and their allies. U.S. Natl. Mus. Bull. 179. Washington, D.C.

Bent, A.C., 1950d. Life histories of North American wood warblers. U.S. Natl. Mus. Bull. 203. Washington, D.C.

Best, L.B. and Stauffer, D.F., 1980. Factors affecting nesting success in riparian bird communities. Condor, 82:149-158.

Blanchard, B., 1991. Wildlife in a changing world: urban challenges for the Fish and Wildlife Service. In: L.W. Adams and D.L. Leedy (Editors) Wildlife conservation in metropolitan environments. Proceedings of a National Symposium on Urban Wildlife. Natl. Inst. Urban Wildl., Columbia, MD, pp.15-18.

Brinson, M.M., Swift, B.L., Plantico, R.C. and Barclay, J.S., 1981. Riparian ecosystems: Their ecology and status. U.S. Fish and Wildlife Service, Biological Service Program. FWS/OBS-81/17. Washington, D. C. 151pp.

Brittingham, M.C. and Temple, S.A., 1983. Have cowbirds caused forest songbirds to decline? BioScience, 33:3135.

Churcher, P.B. and Lawton, J.A., 1987. Predation by domestic cats in an English village. J. Zool., 212:439-455.

Christman, S.P., 1984. Plot mapping: estimating density of breeding bird territories by combining spot mapping and transect techniques. Condor, 86:237-241.

DeGraaf, R.M. and Wentworth, J.M., 1986. Avian guild structure and habitat associations in suburban bird communities. Urban Ecol., 9:399-412.

Dowd, C., 1992. Effect of development on bird species composition of two urban forested wetlands in Staten Island, New York. J. Field Ornithol., 63:455-461.

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

Faaborg, J., Brittingham, M., Donovan, T., and Blake, J., 1993. Habitat fragmentation in the temperate zone: A perspective for managers. In: Status and management of neotropical migratory birds. D.M. Finch and P.W. Stangel (Editors), U.S.D.A. Forest Service General Technical Report RM-229, Fort Collins, Col., pp. 331-338.

Faaborg, J., Brittingham, M., Donovan, T., and Blake, J., In press. Neotropical migrants responses to habitat fragmentation in the temperate zone.

Finch, D.M., 1991. Population ecology, habitat requirements, and conservation of neotropical migratory birds. United States Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Col. 26pp.

Fredrickson, L.H., 1979. Lowland hardwood wetlands: current status and habitat for wildlife. In: Wetland function and values: the state of our understanding. P.E. Greeson, J.R. Clark, and J.E. Clark (Editors), America Water Resource Assoc., Minneapolis, Minn., pp. 296-306.

Geis, A.D., 1974. Effects of urbanization and type of urban development on bird populations. In: J.H. Noyes and D.R. Progulski (Editors), wildlife in an urbanizing environment. Univ. Mass. Amherst, Mass., pp. 97-105.

Harris, L.D., 1984. The fragmented forest: Island biogeographic theory and the preservation of biotic diversity. University of Chicago Press, Chicago, Ill., 211 pp.

Hobbs, E.R., 1988. Using ordination to analyze the composition and structure of urban forest islands. For. Ecol. Manage., 23:139-158.

James, F.C. and Shugart H.H., 1970. A quantitative method of habitat description. Audubon Field Notes, 24:727-736.

Linhart, S.B. and Knowlton, F.F., 1975. Determining the relative abundance of coyotes by scent station lines. Wildl. Soc. Bull., 3:119-124.

Lugo, A.E., Brown, S., and Brinson, M.M., 1990. Concepts in wetland ecology. In: A.E. Lugo, M.M Brinson, and S. Brown (Editors), Ecosystems of the world 15, Forested wetlands. Elsevier, New York, N.Y. pp. 53-85.

Martin, T.E. and Roper, J.J., 1988. Nest predation and nest site selection of a western population of the hermit thrush. Condor, 90:51-57.

Matthiae, P.E. and Stearns, F., 1981. Mammals in forest islands in southeastern Wisconsin. In: R.L. Burgess and D.M. Sharpe (Editors), Forest island dynamics in man dominated landscapes. Springer-Verlag, New York, N.Y. pp. 55-66.

Minnesota Valley National Wildlife Refuge Draft Environmental Impact Statement, 1978. Division of Refuges and Wildlife Planning Section. Region 3, Minneapolis-St. Paul, Minn.

Mitch, W.J. and Gosselink, J.G., 1986. Wetlands. Van Nostr and Reinhold, New York, N.Y. 537pp.

Nilon, C.H. and VanDruff, L.W., 1987. Analysis of small mammal community data and applications to management of urban greenspaces. In: L.W. Adams and D.L. Leedy (Editors), proceedings of a National Symposium on Urban Wildlife. Natl. Inst. Urban Wildl., Columbia, MD, pp. 53-59.

Robinson, S.K., Grzybowski, J.A., Rothstein, S.I., Brittingham, M.C., Petit, L.J., and Thompson, F.R., 1993. Management implications of cowbird parasitism on neotropical migrant songbirds. In: D.M. Finch and P.W. Stangel (Editors), Status and management of neotropical migratory birds, U.S.D.A. Forest Service General Technical Report, RM-229, Fort Collins, Col., pp.93-102.

SAS Institute, 1989. SAS user's guide: statistics, version 6 edition. SAS Institute, Cary, N.C. 1686pp.

Saunders, D.A., Hobbs, R.J., and Margules, C.R., 1991. Biological consequences of ecosystem fragmentation: A review. Conserv. Biol., 5:18-32.

Shafer, C.L., 1990. Nature reserves: Island theories and conservation practice. Smithsonian Institute Press, Washington D.C., 189 pp.

Small, M.F. and Hunter, M.L., 1988. Forest fragmentation and avian nest predation in forested landscapes. Oecologia, 76:62-64.

Smith, R.J. and Schaefer, J.M., 1992. Avian characteristics of an urban riparian corridor. Wilson Bull., 104:732-738.

Soule, M.E., 1986. Conservation biology: The science of scarcity and diversity. Sinauer Associates, Inc., Sunderland, Mass. 233 pp.

Soule, M.E., Bolger, D.T., Alberts, A.C., Wright, J., Sorice, M. and Hill, S., 1988. Reconstructed dynamics of rapid extinctions of chaparral-requiring birds in urban habitat islands. Conserv. Biol., 2:75-92.

Swift, B.L., Larson, J.S., and DeGraaf, R.M., 1984. Relationships of breeding bird density and diversity to habitat variable in forested wetlands. Wilson Bull., 96:48-59.

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

ter Braak, C.J.F., 1987. CANCO--a FORTRAN program for canonical community ordination by [partial] [detrended] [canonical] correspondence analysis and redundant analysis (version 2.1). TNO Institute of Applied Computer Science, Wageningen, The Netherlands, 95 pp.

ter Braak, C.J.F. and Prentice, J.C., 1988. A theory of gradient analysis. Advances in Ecological Research 18:272-327.

Tilghman, N.G., 1987. Characteristics of urban woodlands affecting breeding bird diversity and abundance. i Landscape Urban Plann., 14:481-495.

VanDruff, L.W. and Rowse, R.N., 1986. Habitat associations of small mammals in Syracuse, New York. Urban Ecol., 9:413-434.

Warner, D.W., 1979. Wildlife inventory of the Lower Minnesota River Valley. Report to U. S. Fish and Wildlife Service, Twin Cities, Minn. (unpublished).

Wilcove, D.S., 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecol., 66:1211-1214.

Wilkinson, L., 1990. SYSTAT: The system for statistics. SYSTAT, Inc. Evanston, Ill. 677 pp.

Weisbrod, A.R., Burnett, C.J., Turner, J.G., and Warner, D.W., 1993. Migrating birds at a stopover site in the Saint Croix River Valley. Wilson Bull., 105:265-284.

Yahner, R. and Scott, D.P., 1988. Effects of forest fragmentation on depredation of artificial nests. J. Wild. Manage., 52:158-161.

Chapter 4
Conclusion

This two year study was conducted at the Minnesota Valley National Wildlife Refuge to evaluate the impact of adjacent land use practices on floodplain forest bird communities. If the impacts of adjacent land use are better understood, attempts could be made to further protect the critical habitats of this urban refuge. Sound land use practices adjacent to refuges may be key to maintaining habitat integrity.

Both the winter and breeding bird communities were studied in floodplain forests adjacent to commercial, industrial, residential, and agricultural land use and within these land use areas themselves. In both the winter and breeding season, the floodplain forests supported a bird community that was distinct from the adjacent land use areas. The floodplain forest sites also had higher mean species richness than the sites in the adjacent land use.

The presence of these floodplain forests provides the residents of the Twin Cities with access to a diverse avian community within the metropolitan area. The educational value of these forests should not be underestimated. Exposing the urban residents to these bird communities can only heighten their environmental awareness. Faaborg et al. (1993) emphasized the role that urban woodlands play in maintaining popular interest in neotropical migrants.

<PAGE 92 MISSING FROM HARD COPY>

represent successional changes and this site functions less like a floodplain forest than the other sites.

Natural resource managers should recognize the potential consequences of habitat alteration resulting from adjacent land use practices. Refuges are actually patches linked to a surrounding matrix, and as such, may be influenced by activities in the adjacent areas. Activities associated with the land use may change the habitat structure, leading to changes in the bird communities. For future purchases or buffering reasons, it seems to be critical to ensure that the flooding regime of the forest is maintained as well as habitat structure.

This study has provided valuable information on the potential impacts of adjacent land use on the floodplain forest bird communities. Researchers and natural resource managers should consider this information when designing and managing refuges in urban environments. Research on this topic can not stop here. Future studies should attempt to better quantify the impacts of adjacent land use on habitat structure, predator and nest predator densities and further determine their relationship with the bird communities. Studies are also needed on the avian productivity of these floodplain forest stands. Aspects of the adjacent land use, such as successional changes, increase in nest predators and parasites, human disturbances etc., may substantially decrease reproductive success.

Appendix A. Bird species codes, common names, and scientific names.

Species Code	Common Name	Scientific Name
AMCR	American crow	Corvus brachyrhynchos
AMGO	American goldfinch	Carduelis tristis
AMKE	American kestrel	Falco sparverius
AMRE	American redstart	Setophaaa ruticilla
AMRO	American robin	Turdus miaratorius
ATSP	American tree sparrow	Spizella arborea
BDOW	Barred owl	Strix varia
BASW	Barn swallow	Hirundo rustica
BAWW	Black-and-white warbler	Mniotilta varia
BCCH	Black-capped chickadee	Parus atricapillus
BEKI	Belted kingfisher	Ceryle alcyon
BGGN	Blue-grey gnatcatcher	Polioptila caerulea
BHCO	Brown-headed cowbird	Molothrus ater
BLJA	Blue jay	Cyanocitta cristata
BRCR	Brown creeper	Certhia americana
CEWA	Cedar waxwing	Bombycilla cedrorum
CHSP	Chipping sparrow	Spizella passerina
COGR	Common grackle	Quiscalus quiscula
CONI	Common nighthawk	Chordeiles minor
CORE	Common redpoll	Carduelis flammea
COYE	Common yellowthroat	Geothlypis trichas
DEJU	Dark-eyed junco	Junco hyemalis
DICK	Dickcissel	Spiza americana
DOWO	Downy woodpecker	Picoides gubescens
EAKI	Eastern kingbird	Tyrannus tyrannus
EAME	Eastern meadowlark	Sturnella magna
EAPH	Eastern pheobe	Sayornis phoebe
ESOW	Eastern screech owl	Otus asio
EUST	European starling	Sturnus vulgaris
EWPE	Eastern wood pewee	Contopus virens
FISP	Field sparrow	Spizella Qusilla
GCFL	Great-crested flycatcher	Myiarchus crinitus
GRCA	Grey catbird	Dumetella carolinensis
GRSP	Grasshopper sparrow	Ammodramus savannarum
HAWO	Hairy woodpecker	Picoides villosus
HETH	Hermit thrush	Catharus guttatus
HOFI	House finch	Carpodacus erythrinus
HOSP	House sparrow	Passer domesticus
HOWR	House wren	Troglodytes aedon
INBU	Indigo bunting	Passerina cvanea
KILL	Killdeer	Charadrius vociferus
LEFL	Least flycatcher	Epidonax minimus
MALL	Mallard	Anas platvrhynchos
MODO	Morning dove	Zenaidura macroura

Appendix A. Continued.

NOCA	Northern cardinal	Cardinalis cardinalis
NOFL	Northern flicker	Colantes aurtatus
NOOK	Northern oriole	Icterus galbula
PIWO	Pileated woodpecker	Dryocopus pileatus
POWA	Prothontary warbler	Pronotaria citrea
RBGR	Rose-breasted grosbeak	Pheucticus ludovicianus
RBWO	Red-bellied woodpecker	Melanerpes carolinus
REVI	Red-eyed vireo	Vireo olivaceus
RHWO	Red-headed woodpecker	Melanerpes erythrocephalus
RNPH	Ring-necked pheasant	Phasianus colchicus
RWBL	Red-winged blackbird	Aaelaius phoeniceus
SOSP	Song sparrow	Melospiza melodia
SWTH	Swainson's thrush	Catharus ustulatus
TRSW	Tree swallow	Tachycineta bicolor
WAVI	Warbling vireo	Vireo Qilvus
WODU	Wood duck	Aix sponsa
YEWA	Yellow warbler	Dendroica getechia

Appendix B. Bird species codes and life history groupings.

Species Code	TOTBD	INTRO	NATV	INSECT	SDOMNI	NEO	NPP
AMCR	X		X		X		X
AMGO	X		X		X		
AMKE	X		X			X	
AMRE	X		X	X		X	
AMRO	X		X		X	X	
ATSP	X		X		X		
BDOW	X		X				
BASW	X		X	X		X	
BAWW	X		X	X		X	
BCCH	X		X		X		
BEKI	X		X			X	
BGGN	X		X	X		X	
BHCO	X		X		X	X	X
BLJA	X		X		X		X
BRCR	X		X	X			
CEWA	X		X		X	X	
CHSP	X		X		X	X	
COGR	X		X		X		X
CONI	X		X	X		X	
CORE	X		X		X		
COYE	X		X	X		X	
DEJU	X		X		X		
DICK	X		X		X	X	
DOWO	X		X	X			
EAKI	X		X	X		X	
EAME	X		X		X		
EAPH	X		X	X		X	
ESOW	X		X				
EUST	X	X			X		
EWPE	X		X	X		X	
FISP	X		X		X	X	
GCFL	X		X	X		X	
GRCA	X		X		X	X	
GRSP	X		X		X	X	
HAWO	X		X	X			
HETH	X		X	X		X	
HOFI	X		X		X		
HOSP	X	X			X		
HOWR	X		X	X		X	
INBU	X		X		X	X	
KILL	X		X	X			
LEFL	X		X	X		X	
MALL	X		X		X		
MODO	X		X		X		
NOCA	X		X		X		
NOEL	X		X	X			
NOOR	X		X		X	X	

Appendix B. continued.

Species code	TOTBD	INTRO	NATV	INSECT	SDOMNI	NEO	NPP
PIWO	X		X	X			
POWA	X		X	X		X	
RBGR	X		X		X	X	
RBWO	X		X	X			
REVI	X		X	X		X	
RHWO	X		X	X			
RNPH	X	X			X		
RODO	X	X			X		
RWBL	X		X		X	X	
SOSP	X		X		X		
SWTH	X		X	X		X	
TRSW	X		X	X		X	
WAVI	X		X	X		X	
WBNU	X		X	X			
WODU	X		X		X		
YEWA	X		X	X		X	

Appendix C. Common and scientific names of mammalian species.

Common name	Scientific name
Beaver	Castor canadensis
Domestic cat	Felix cattus
White-tailed deer	Odocoileus virginianus
Domestic dog	Canus familiarus
Muskrat	Ondatra zibethica
Eastern cottontail rabbit	Sylvilacrus floridanus
Raccoon	Procyon otor
Red fox	Vulges vulpes
Striped skunk	Mephitis mephitis
Squirrel spp.	Scuiurus spp.
Woodchuck	Marmota monax

<APPENDIX D-1ST PAGE MISSING FROM HARD COPY>

Appendix D. Continued.

WAVI*	0.13	0
WBNU*	0.37	0.01
WODU	0.01	0
YEWA*	0.56	0

*Differences among sites ($\underline{P} < 0.05$)

Appendix E. Mean avian density (birds/ha) for the floodplain forest sites during the
1992 breeding season.

		Sites		
Species	RSI	CSI	AGI	INI
AMGO*	0.14b	0b	0.03b	0.67a
AMRE	0.03	0.17	0.06	0.11
AMRO*	0.19c	0.61b	1.27a	0.38bc
BAOW	0.06	0	0	0
BCCH*	0.83a	0.25b	0.15b	0.25b
BHCO	0	0.03	0.15	0.06
BLJA*	033a	0.17b	0.15bc	0.03c
BRCR	0	0.11	0	0
CEWA	0	0	0	0.08
COGR	0	0	0	0.06
COYE*[a]	0.36b	0.25bC	0.82a	0.06d
DOWO*	0.50a	0.25c	0.15c	0.44ab
EUST	0	0	0.03	0.03
EWPE	0.19	0.25	0.18	0.31
GCFL*[a]	0.67a	0.39b	0.33bc	0.08d
GRCA*[a]	0.06b	0.08b	0.09b	0.36a
HAWO[a]	0.11	0	0.03	0.03
HETH	0	0.03	0	0
HOSP	0	0	0	0.03
HOWR*	2.OOc	2.83a	1.09d	2.72ab
INBU	0.08	0	0	0
LEFL*[a]	0b	0.08b	0.03b	1.33a
MODO	0	0	0.06	0
NOCA*	0.31ab	0.08c	0c	0.36a
NOOR	0.08bc	0.03c	0.15b	0.47a
PIWO	0.03	0	0	0
POWA	0	0.03	0	0
RBGR*	0.06bc	0c	0.18a	0.14ab
RBWO	0.08	0.03	0.12	0
REVI*	0.06b	0.50a	0.12b	0.08b
RHWO*[a]	0b	0b	0.42a	0b
RWBL	0	0	0.12	0
SCOW	0	0.03	0	0
SOSP*	0.33b	0.42b	1.09a	0.47b
WAVI*[a]	0	0.08b	0b	0.42a
WBNU*	0.75a	0.31b	0.24b	0.16b
WODU[a]	0	0	0.03	0
YEWA*[a]	0b	0b	0b	2.19a

* Differences among sites ($\underline{P} < 0.05$)
Values with different letters are significantly ($\underline{P} < 0.05$) different
[a]Species identified via ordination

Appendix F. Mean avian density (birds/ha) for the adjacent land use sites during the 1992 breeding season.

Species	Sites			
	RSO	CSO	AGO	INO
AMCR	0.10	0.03	0	0.04
AMGO*	0.13b	0.67a	0.37b	0b
AMRE	0	0.07	0	0
AMRO*	1.10a	0.43b	0.04c	0.26bc
BASW*	0b	0b	0b	0.15a
BCCH	0.13	0.03	0.04	0
BHCO*	0.07c	0.67a	0.63ab	0.15c
BLJA*	0.17a	0.07ab	0b	0b
CHSP*	0.17a	0.13ab	0.07bc	0c
COGR	0.30	0.13	0.30	0.22
COYE	0	0.07	0.26	0.04
DICK*	0b	0b	0.78a	0b
DOWO	0.03	0	0.04	0
EAKI*	0.07b	0b	0.33a	0b
EAME*	0b	0b	0.59a	0b
EUST*	0.23b	0.17b	0.19b	0.93a
GRSP*	0b	0b	0.44a	0b
HOSP*	1.93b	2.57bc	0c	10.22a
HOWR*	0.53a	0.30ab	0c	0c
INBU*	0.03b	0.13a	0.04b	0b
KILL*	0.07b	0.03b	0b	0.41a
MODO*	0.07b	0b	0.48a	0b
NOCA*	0.17a	0b	Ob	Ob
RBWO	0	0	0.04	0
RODO*	0b	0b	0b	0.20a
RWBL*	0b	0b	1.44a	0.07b
SOSP	0	0	0.19	0
TRSW	0	0	0.07	0
WBNU	0.03	0	0	0

* Differences among sites ($\underline{P} < 0.05$)
Values with different letters are significantly ($\underline{P}$ 0.05) different

Appendix G. Mean avian density for the floodplain forest and adjacent land use sites during the 1993 breeding season.

	Sites	
Species	Floodplain forest	Adjacent land use
AMCR	0.02	0.03
AMGO	0.14	1.15
AMKE	0	0.01
AMRE*	0.45	0.01
AMRO	0.48	0.40
BAOW	0.01	0
BASW*	0	0.05
BAWW	0.20	0
BCCH*	0.20	0.03
BEKI	0	0.01
BGGN*	0.16	0
BHCO*	0.04	0.13
BLJA*	0.07	0.01
BRCR	0.03	0
CHSP	0	0.02
COGR*	0.01	0.15
CONI	0	0.01
COYE	0.34	0.22
DICK*	0	0.07
DOWO*	0.11	0
EAKI*	0	0.07
EAME*	0	0.21
EAPH	0	0.01
EUST*	0.05	0.64
EWPE*	0.28	0
FISP	0	0.01
GCFL*	0.31	0.02
GRCA	0.04	0.01
HAWO*	0.14	0.01
HOFI	0	0.03
HOSP*	0	1.78
HOWR*	1.12	0.08
INBU	0	0.02
KILL*	0	0.29
LEFL*	0.20	0
MALL	0	0.04
MODO*	0.01	0.07
NOCA*	0.13	0.04
NOFL	0.01	0.01
NOOR*	0.08	0.01
PIWO	0.01	0
POWA	0.01	0
RBGR*	0.06	0

Appendix G. continued.

RBWO*	0.03	0
RNPH	0	0.02
REVI*	0.36	0
RWBL*	0.01	0.25
SOSP*	0.30	0.16
SWTH	0.01	0
TRSW*	0.0	0
WAVI*	0.14	0
WBNU*	0.27	0.02
WODU*	0.09	0
YEWA*	0.25	0.01

*Differences among sites ($\underline{P} < 0.05$)

Appendix H. Mean avian density (birds/ha) for the floodplain forest sites during the 1993 breeding season.

	Sites			
Species	RSI	CSI	AGI	INI
AMCR	0.05	0.02	0	0
AMGO*	0.25a	0b	0.03b	0.29a
AMRE*	0.05c	0.93a	0.05c	0.71b
AMRO*	0.05b	0.40a	0.59a	0.86a
BAOW	0	0	0	0.02
BAWW*	0b	0.07a	0b	0b
BCCH*	0.36a	0.17b	0.13b	0.17b
BGGN*	0b	0.26a	0.03b	0.33a
BHCO*	0.03ab	0b	0b	0.14a
BLJA*a	0.21a	0b	0.10ab	0b
BRCR	0	0.12	0	0
COGR	0	0	0.03	0
COYE*	0.31b	0.29b	0.59a	0.19b
DOWO	0.15	0.12	0.05	0.12
EUST*	0b	0b	0.21a	0b
EWPE*	0.23b	0.29ab	0.46a	0.17b
GCFL*a	0.64a	0.31b	0.31b	0C
GRCA*a	0b	0b	0b	0.17a
HAWOa	0.18	0.10	0.23	0.07
HOWR*	0.77b	1.24a	0.97b	1.48a
LEFL*[a]	0b	0b	0.05b	0.74a
MODO	0	0	0.05	0
NOCA*	0.26a	0.07b	0.13ab	0.07b
NOFL	0	0	0.03	0
NOOR*	0.03b	0b	0.15a	0.17a
PIWO	0	0	0.03	0
POWA	0	0.02	0	0
RBGR*	0.08ab	0.02bc	0c	0.14a
RBWO	0.05	0	0.05	0.02
REVI*	0.31b	0.64a	0.31b	0.17c
RWBL	0	0	0.05	0
SOSP*	0.26bc	0.31b	0.51a	0.12c
SWTH	0	0.04	0	0
TRSW*	0.18a	0.12b	0c	0c
WAVI*[a]	0b	0.02b	0.03b	0.50a
WBNU*	0.21ab	0.23ab	0.46a	0.19b
WODU*[a]	0.26a	0.10b	0.03b	0b
YEWA*[a]	0b	0b	0b	0.95a

* Differences among sites ($\underline{P} < 0.05$)
Values with different letters are significantly ($\underline{P} < 0.05$) different
[a] Species identified via ordination

Appendix I. Mean avian density (birds/ha) for the adjacent land use site during the 1993 breeding season.

	Sites			
Species	RSO	CSO	AGO	INO
AMCR	0.03	0.05	0.03	0.02
AMGO*	0.08b	0.40a	0.08b	0.02b
AMKE	0	0	0.03	0
AMRE	0	0.02	0	0
AMRO*	0.72a	0.50a	0.13b	0.24b
BASW*	0.15a	0b	0b	0.05b
BCCH	0.13	0	0	0
BEKI	0	0	0.03	0
BHCO*	0.23a	0.17a	0.13a	0b
BLJA	0.05	0	0	0
CHSP	0.03	0.02	0.03	0
COGR	0.23	0.02	0.08	0.26
CONI	0.03	0	0	0
COYE*	0.15bc	0.31ab	0.36a	0.07c
DICK*	0b	0b	0.31a	0b
EAKI*	0.18a	0.10ab	0.03bc	0c
EAME*	0b	0b	0.87a	0b
EAPH*	0.05a	0b	0b	0b
EUST*	0.69b	0.67b	0.03c	1.14a
FISP	0	0	0.03	0
GCFL	0.03	0.05	0	0
GRCA	0	0.02	0	0
HAWO	0.03	0	0	0
HOFI	0	0.05	0	0.07
HOSP*	1.56b	0.62c	0d	4.79a
HOWR*	0.23a	0.07ab	0.03b	0b
INBU	0.05	0.02	0	0
KILL*	0b	0b	0b	1.12a
MALL*	0b	0b	0b	0.14a
MODO*	0.05b	0b	0.03b	0.21a
NOCA	0.13	0	0.03	0
NOFL	0	0.02	0	0
NOOR	0	0	0.03	0
RNPH*	0b	0b	0.08a	0b
RWBL*	0.03b	0.03b	0.92a	0.07b
SOSP*	0b	0b	0.62a	0.04b
WBNU	0.10	0	0	0
YEWA	0.03	0	0	0

* Differences among sites ($\underline{P} < 0.05$)
Values with different letters are significantly ($\underline{P} < 0.05$) different