Large-scale Habitat Relationships of Neotropical Migratory Birds

by

Mark E. Penhollow

Thesis submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

IN

FISHERIES AND WILDLIFE SCIENCES

APPROVED:

Dean F. Stauffer, Chair

Carola A. Haas

Roy L. Kirkpatrick

November, 1996

Blacksburg, Virginia

Keywords: Songbirds, Habitat, Modeling, Scale, Landscape

LARGE-SCALE HABITAT RELATIONSHIPS
OF NEOTROPICAL MIGRATORY BIRDS

by

Mark E. Penhollow

Dean F. Stauffer, Chair

Fisheries and Wildlife Sciences

(ABSTRACT)

I examined the relationship of bird assemblages and species to habitat patterns over landscapes composed of a mosaic of habitat elements. I surveyed songbirds using a variation of the variable circular plot method during the 1994 and 1995 breeding seasons on 20 sites ranging in size from 50 to 72 ha on the Quantico Marine Corps Base, VA. Measures of community performance including species diversity, species richness, species equitability, and indices of relative abundance were calculated for each site. I determined the large-scale habitat characteristics of each site by analyzing coverages of each site from Quantico's GIS database using FRAGSTATS. Landscape patches were defined using 2 different classification schemes to determine if both SAF cover type and generalized habitat classifications could be used to determine which large-scale habitat elements influence bird species and assemblages. I used stepwise multiple regression and stepwise logistic regression to determine which large-scale habitat measures and combinations thereof were associated with high and low measures of community performance.

Diversity as measured by the Shannon-Wiener diversity index and the Simpson's diversity index was positively related to the amount of high-contrast edge in a landscape in

the SAF cover type based analysis. In the generalized habitat type based analysis, diversity was positively related to the number of different patch types per unit area in a landscape and negatively related to the percentage of hardwood forest in a landscape.

The number of different patch types per unit area, the amount of contrast-weighted edge per unit area, and the percentage of mixed pine/hardwood forest in a landscape were selected most frequently as significant predictors of individual species relative abundance in both the SAF cover type and generalized habitat type based analyses.

Habitat diversity was the most important factor influencing the large-scale selection of habitat by bird species on Quantico. With respect to individual species models, the 2 analyses yielded comparable results, and I believe that many of the common bird species occurring on Quantico can be managed according to either the SAF cover type classifications or the generalized habitat type classifications.

Acknowledgments

I would first and foremost like to thank my advisor, Dean Stauffer, for his guidance, his generosity, and his patience. I could not have hoped for a better mentor. He made my tenure at Virginia Tech a truly rewarding experience.

I thank Drs. Carola Haas and Roy Kirkpatrick for whom I have the greatest respect and admiration. I greatly appreciate the help and advice they gave me throughout the development of my thesis.

Financial support for this project was provided by the National Biological Service and the U.S. Department of the Navy through the Natural Resources and Environmental Affairs Branch of the Quantico Marine Corps Base. I would especially like to thank Tim Stamps for his enthusiasm for the project and for providing invaluable logistic support during my field seasons. Also, I thank Meeghan Wallace for her thoughtfulness and for going out of her way on countless occasions to help me with a plethora of obstacles.

I am grateful to my 2 technicians, Mark Banker and Jennifer Ehrenberger, for braving the early morning hours, the long work weeks, the ticks, the heat and humidity, and the war-games. I thank them for their dedication to my project and for working harder than any reasonable person should have to.

My deepest appreciation to my fellow graduate students, the faculty, and staff for their help and moral support. It was a pleasure to have had the opportunity to meet so many wonderful people and make so many close friends.

I cannot fully express my gratitude to my fiancé, Susan Hayes, for her enduring patience, her love, and her encouragement. Susan, thank you for giving me something to look forward to. I am blessed to have you in my life.

Finally, I would like to thank my family who are my greatest source of strength. Their support is the foundation for all my efforts and aspirations. They have made this thesis possible.

Table of Contents

INTRODUCTION 1

STUDY AREA 5

STUDY SITE SELECTION 6

FIELD METHODS 8

Birds 8

Habitat 9

ANALYTICAL METHODS 10

Birds 10

Habitat 10

Data Analysis 15

RESULTS 16

Models Based On SAF Cover Type Classifications 16

Habitat Measures. 16

Bird Assemblage Models. 20

Species Abundance Models.-- *Multiple Regression Analysis* 21

Species Abundance Models.-- *Logistic Regression Analysis* 24

Models Based On Generalized Habitat Type Classifications 25

Habitat Measures 25

Bird Assemblage Models. 26

Species Abundance Models.-- *Multiple Regression Analysis* 31
Species Abundance Models.--*Logistic Regression Analysis* 34
DISCUSSION 36
Assemblage Measures 38
SAF Cover Type Summary 38
Generalized Habitat Type Summary 39
Species Abundance Measures 41
Patch Richness Density 41
Percentage of Pine/Hardwood Forest 46
Contrast-weighted edge density 47
Number of Core Areas 48
Edge density 50
SAF Cover Type vs. Generalized Habitat Type 50
Management Implications 53
Limitations 54
LITERATURE CITED 57
APPENDICES 63

List of Figures

Figure 1. Distribution of study sites on the Quantico Marine Corps Base, Quantico, VA. 1994-1995 7

List of Tables

Table 1. Mnemonic codes, definitions, and formulas for measures used to describe bird assemblages in study sites on the Quantico Marine Corps Base, VA. 1994 and 1995 11

Table 2. SAF cover type and generalized habitat type classifications used to define forest stands on the Quantico Marine Corps Base, VA. 1994 and 1995. 13

Table 3. Habitat measures used as independent variables in the development of multiple regression and logistic regression models for bird species and assemblages on the Quantico Marine Corps Base, VA. 1994 and 1995. 14

Table 4. Regression coefficients from stepwise multiple linear regression analyses for bird assemblages and species occurring in $\geq$ 17 sites, Quantico Marine Corps Base, VA. 1994 and 1995. Analyses were based on SAF cover type classifications. . 17

Table 5. Estimated coefficients and predictability of models generated from stepwise logistic regression analyses for predicting the presence or absence of bird species on study sites, Quantico Marine Corps Base, VA. 1994 and 1995. Analyses were based on SAF cover type classifications. 19

Table 6. Regression coefficients from stepwise multiple linear regression analyses for bird assemblages and species occurring in $\geq$ 17 sites, Quantico Marine Corps Base, VA. 1994 and 1995. Analyses were based on generalized habitat type classifications. 27

Table 7. Estimated coefficients and predictability of models generated from stepwise logistic regression analyses for predicting the presence or absence of bird species on study sites, Quantico Marine Corps Base, VA. 1994 and 1995. Analyses were based on generalized habitat type classifications. 29

List of Appendices

Appendix A. Mnemonic codes and scientific names of bird species detected on the Quantico Marine Corps Base, VA. 1994 and 1995. 64

Appendix B. Correlation coefficients (r) from correlation analyses for bird assemblages and species occurring in ≥ 17 sites, Quantico Marine Corps Base, VA. 1994 and 1995. Analyses were based on classifications of SAF cover types....... 66

Appendix C. Correlation coefficients (r) of correlation analyses for bird assemblages and species occurring in ≥ 17 sites, Quantico Marine Corps Base, VA. 1994 and 1995. Analyses were based on generalized habitat type classifications...... 68

Appendix D. Summary statistics for landscape measures generated from the analysis of 20 sites based on SAF Cover Type classifications of patches, Quantico Marine Corps base, VA. 1994 and 1995. 70

Appendix E. Summary statistics for landscape measures generated from the analysis of 20 sites based on generalized habitat type classifications of patches, Quantico Marine Corps Base, VA. 1994 and 1995. 71

Appendix F. Bird assemblage measures by site on the Quantico Marine Corps Base, VA. 1994 and 1995. 72

Appendix G. Habitat measures by site based on generalized habitat type classifications, Quantico Marine Corps Base, VA. 1994 and 1995. 73

Appendix H. Habitat measures by site based on SAF cover type classifications, Quantico Marine Corps Base, VA. 1994 and 1995. 74

Appendix I. Species abundance indices by site for the Quantico Marine Corps Base, VA. 1994 and 1995. 75

Appendix J. Density estimates (#/ha) calculated by site for species with ≥ 20 observations in a given site on the Quantico Marine Corps Base, VA. 1994 and 1995... 85

Appendix K. Edge-contrast weights for combinations of patches defined using SAF cover type classifications on study sites, Quantico Marine Corps Base, VA. 1994 and 1995. 87

Appendix L. Edge-contrast weights for combinations of patches defined using generalized habitat type classifications on study sites, Quantico Marine Corps Base, VA. 1994 and 1995. 88

Appendix M. Study sites with patches defined using SAF cover types and generalized habitat types, Quantico Marine Corps Base, VA. 1994-1995. 89

INTRODUCTION

There is a growing concern over the status of many species of North American breeding birds. This concern is based on the numerous studies that have indicated breeding bird populations have declined dramatically during the last several decades in many parts of North America (Wilcove and Terborgh 1984, Morton and Greenberg 1989, Terborgh 1989, Askins et al. 1990). This decline is particularly well documented for populations of Neotropical migratory birds that breed in forests and grasslands of the eastern United States and Canada (Hutto 1988, Robbins et al. 1989, Johnston and Hagan 1989). The 2 primary causes cited for the serious decline of Neotropical migrants are fragmentation of habitat on their temperate breeding grounds and the large-scale loss of habitat on their tropical wintering grounds, both a result of urban and suburban expansion, agriculture, and deforestation (Terborgh 1989, Askins et al. 1990, Finch 1991). There is some debate as to which of these has the greatest impact on Neotropical migrants. There is a substantial amount of evidence supporting each and some researchers believe the decline is likely a function of the cumulative effects of both (Morton and Greenberg 1989, Askins et al. 1990).

Studies on the effects of forest fragmentation on breeding birds in the eastern United States are extensive and indicate that the detrimental effects of forest fragmentation on Neotropical migrants are numerous (see review in Askins 1990). Among them are loss of habitat, higher predation rates, increased cowbird parasitism, and increased intraspecific and interspecific competition (Whitcomb et al. 1981, Brittingham and Temple 1983, Wilcove 1985, Hutto 1988, Terborgh 1989, Faaborg et al. 1993).

There is an urgency to develop management plans that will improve the quality (and possibly quantity) of habitat for Neotropical migrants. This urgency has led to a surge in research on the needs of Neotropical migrants and on their relationship to their environment (Askins et al. 1990). Neotropical migratory birds represent a diverse group of organisms that require a broad array of often disparate habitat conditions. Developing management plans for their protection and recovery is therefore complicated. A relatively new approach in dealing with this problem is the development of statistical models that simplify the relationships between birds and habitat and facilitate population management (Schamberger and O'Neil 1986).

Modeling wildlife-habitat relationships has become an increasingly useful tool in contemporary wildlife management, particularly with respect to birds (Verner 1986). Knowledge of ecological relationships has broadened immensely in recent history and has shown how complex and intricate the relationships between wildlife and habitat truly are. Modeling is one potentially effective solution to the problem of managing dynamic wildlife populations in a highly varied and changing environment (Shugart and Urban 1986). Habitat models may be used to predict the distribution and abundance of species, assess the suitability of habitat, and to predict what effects changes in habitat might have on a population. Wildlife-habitat relationship modeling has traditionally been limited to a single species [e.g. Habitat Suitability Index (HSI) models, Pattern Recognition (PATREC) models, Habitat Capability (HC) models] (Berry 1986). However, as our knowledge of ecological processes expands, so does the development of modeling techniques. The trend in modeling has been from single species models to multiple species or community models. The obvious advantage to multiple species models is the ability to manage an assemblage of species under a single management plan (Graul and Miller 1984, Schroeder 1992).

A common approach to understanding the relationships of bird species and habitat is to examine the relationship of a single bird species to a specific vegetative character such as what might be found in an individual's territory (Shugart and Urban 1986). However, it is evident that bird populations are limited not only by the individual patches they occupy but are affected by the surrounding landscape as well (Freemark et. al. 1993).

Freemark and Collins (1989) discussed this relationship in terms of *landscape context*. They found that the relationship of forest fragments to the surrounding landscape, specifically to the proportion of forest nearby or the proximity to larger forests, affected the abundance and distribution of bird species. Similarly, Whitcomb et al. (1981) found that the degree of isolation of forest fragments significantly influenced the distribution and abundance of bird species. They acknowledged that the concept of landscape context goes much further and includes the interrelatedness of forest patches within forest fragments. They presented a number of examples that illustrate the complex relationship between spatiotemporal habitat heterogeneity and bird distribution and diversity (see review in Whitcomb et al. 1981). Hagan et al. (1995) looked at the importance of landscape context to bird assemblages and species in another way. They calculated a series of contrast indices for stand type, age, and closure which described the degree of difference between a sampled stand and surrounding stands within a 1-km radius. They found that the presence or absence of a number of bird species was related to the amount of similar habitat within a 1-km radius of where the species was detected (homogeneous landscapes).

An important consideration in examining the relationship of birds and habitat is spatial scale. Spatial scale greatly influences the perceived relatedness of bird species and assemblages and habitat (Wiens et al. 1987, Steele 1992). Birds select habitat at a number of different spatial scales. Those habitat features selected at one scale may not be selected at another. Indeed, most of the studies examining habitat associations at more than one spatial scale have found at least some species that selected different habitat features between scales (Steele 1992).

Another important consideration in describing relationships of bird species and habitat is habitat definition. As Whitcomb et al. (1981) aptly point out, "even an apparently uniform expanse of forest is, at some level of discrimination, a mosaic of habitat patches." A landscape mosaic is defined by the patches that compose it. Patches may be defined in narrow or broad terms (Schamberger and O'Neil 1986). The way in which these patches are defined influences the results of habitat models which in turn affects the perceived relatedness of birds and habitat (Schamberger and O'Neil 1986). The perception of the relationship between birds and habitat is particularly important from a management perspective because it is the foundation of avian management and conservation planning.

My approach, then, was to examine the needs of individual species as well as entire assemblages of birds over landscapes composed of a mosaic of habitat elements.

My principle objective was to determine which large-scale habitat elements influence bird assemblage diversity and individual bird species abundance. I had 2 specific objectives:

1. To determine species richness, relative species diversity, and relative abundance of bird assemblages and species on sites of varying landscape diversity.

2. To develop quantitative models for bird assemblages and species based on specific and general habitat classifications.

STUDY AREA

The Quantico Marine Corps Base, Quantico, Virginia is located on the west bank of the Potomac River in Stafford, Prince William, and Fauquier Counties, approximately 35 miles south of Washington, DC. It encompasses > 24,300 hectares and is divided into the eastern Coastal Plain section (2,830 ha) and the western Piedmont Region section (21,530 ha) (Natural Resources Conservation Report 1993). A range of habitat types is represented on Quantico including woodlands, shrublands, grasslands, and wetlands, all of which are subject to natural resource management programs.

Approximately 21,600 ha of Quantico are forested (Natural Resources Conservation Report 1993). General forest cover types include hardwood, pine-hardwood, and pine. Banker (1994) found that most hardwood stands on Quantico were dominated by oaks (*Quercus* spp.), hickories (*Carya* spp.), yellow poplar (*Liriodendron tulipifera*), sweetgum (*Liquidambar styraciflua*) and red maple (*Acer rubrum*). Pine-hardwood stands were dominated primarily by Virginia pine (*Pinus virginianus*) and oak. Pine stands were dominated by either a mixture of loblolly (*P.*

taeda) and shortleaf (*P. echinata*) pine or Virginia pine. Approximately 1,660 ha of Quantico is nonforested habitat; primarily native grass and early successional shrublands. The remaining area is improved grounds, including managed turf grass and developed areas (Natural Resources Conservation Report 1993).

STUDY SITE SELECTION

Ten sites of approximately 60 ha each were stratified randomly selected and established each field season (n = 20) (Figure 1). It was necessary to confine site selection to those areas of the base where daily or every-other-day access was assured. I sampled a gradient of sites with respect to the relative apparent degree of fragmentation or patchiness. To facilitate this, we generated a forest stand coverage map of the base using ArcView (ESRI 1994). I assumed that smaller patches were associated with areas of greater fragmentation and larger patches were associated with areas of lower fragmentation. Each forest stand was classified by size class (<6 ha, 8-15 ha, and 20-30 ha) and assigned a number. Stands within each size class were then selected at random. A clear, plastic template (60 ha) was aligned on the center of the stand and was used to determine the fragmentation category of that potential site. Fragmentation categories were defined by the range of degrees of fragmentation that could reasonably be found on Quantico and included low ($\leq$4 patches), medium (5-7 patches), and high ($\geq$ 8 patches) fragmentation. Sites were selected and categorized until 3 minimally, 4 moderately, and 3 highly fragmented sites were obtained each season.

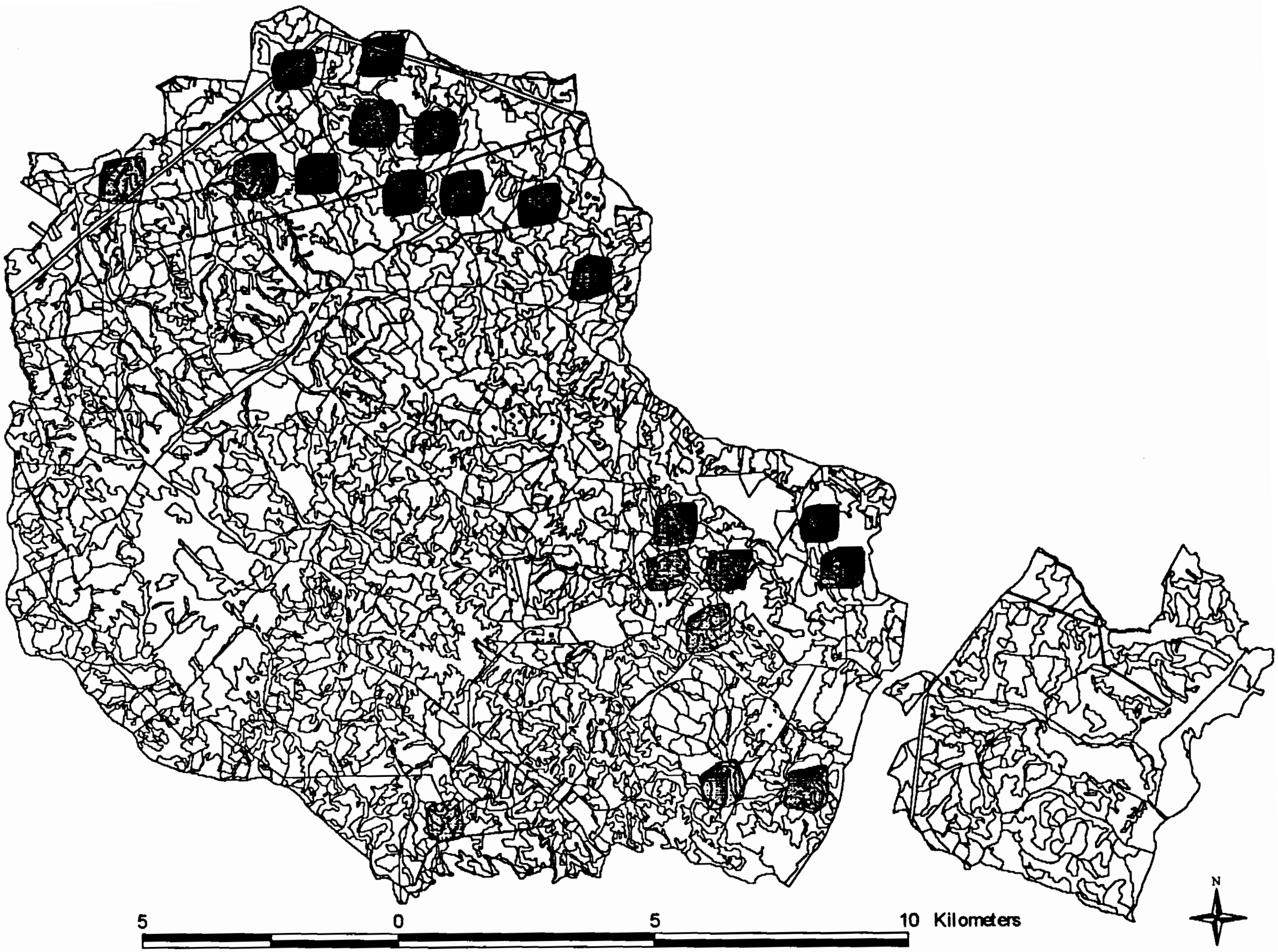


Figure 1. Distribution of study sites on the Quantico Marine Corps Base, Quantico, VA. 1994-1995.

FIELD METHODS

Birds

Data collection began the first week in May and ended the second week in August in 1994 and 1995. A variation of the variable-circular plot method (Reynolds et al. 1980) was utilized. Point-count surveying was chosen over other survey techniques because of its flexibility of use in a variety of habitats, the ability to sample the largest area per unit of effort, and its relative ease of implementation in the field (Verner 1985a, Verner 1985b).

Twelve point-count stations were established at each site. This number represented the number of stations a single observer could effectively cover in 1 survey morning. Stations were evenly distributed (250 m apart) throughout each site starting from a randomly selected location. A separation distance of 250 m was used to obtain an accurate representation of the bird assemblage on each study site while minimizing the likelihood of dual counts of individuals between and among points.

Point-count surveys began 15 minutes prior to official sunrise and continued until each of the 12 stations had been surveyed. Each survey lasted 8 minutes and no acclimation period was used. This survey time period was chosen as a compromise between maximizing the potential number of birds detected during a counting period while minimizing the risk of counting individuals more than once during a single point-count survey (Verner 1988). Additionally, it allowed us to adequately visit and travel between each of the 12 point-count stations within the first 4 hours after sunrise when bird activity is at its daily peak (Robbins 1981). Surveys were not performed during inclement weather including rain, dense fog, and high wind (>10 km/hr).

Prior to the initiation of a survey, the site number, the observer, the date, the visit number, the point-count station number, and the starting time were recorded. When an individual bird was detected, its species was determined and its position from the point was estimated (0m-10m, 11m-20m, 21m-30m, 31m-50m, 71m-90m, >90m). Distance intervals were used to minimize the effects of human error and distance estimation bias. Birds that were detected flying over or through the plot were recorded in a separate category (fly). Additionally, bird species detected within the study site while the observer was traveling between stations (but not detected during surveys) were recorded. These observations were used in the determination of species richness for a particular site only. Each site was surveyed 8 times. After the first 4 sampling periods, the order in which the stations were sampled was reversed so that all stations had an opportunity to be sampled during the early morning peak in bird activity.

Habitat

Habitat data were obtained from the Quantico Marine Corps Base's Geographical Information System (GIS) database. Themes used in the evaluation included forest stands, roads, creeks, ponds, rivers, and topography.

ANALYTICAL METHODS

Birds

Using program DISTANCE (Laake et al. 1993), densities were calculated by site for species having $\geq$20 individuals observed in that site. Additionally, abundance indices, defined as the number of individuals observed of a species per station per visit were calculated for all species on each site. A correlation analysis was performed to determine if density estimates and abundance indices were correlated. The analysis indicated that they were highly correlated and supported the use of abundance indices as appropriate indicators of density.

Four bird assemblage measures were calculated for each site: Simpson's diversity index, the Shannon-Wiener diversity index, Pielou's equitability index (Pielou 1966, Peet 1974, Ludwig and Reynolds 1988, Krebs 1989) and the total number of species detected (Table 1).

Habitat

Habitat was evaluated at a large scale and was analyzed using FRAGSTATS (McGarigal and Marks 1995). The Global Positioning System (GPS) was used to determine the location of each point count station in each site. A coverage of point-count stations was generated in PC Arc Info for each site using the coordinates obtained from GPS. Then in UNIX-Arc Info, a polygon coverage was generated for each site by using the 8 outermost points of each site as vertices. This new polygon coverage was then

Table 1. Mnemonic codes, definitions, and formulas for measures used to describe bird assemblages in study sites on the Quantico Marine Corps Base, VA. 1994 and 1995.

Mnemonic Code	Definition	Formula
TOTSPP	Total number of species detected in site	
H′	Shannon-Wiener Diversity Index	**$\Sigma(p_i)(\log_{10}p_i)$** p_i = Proportion of total sample belonging to the ith species
J	Pielou's Equitability Index	**H'/H_{max}** H' = Shannon-Wiener Index $H'_{max} = \log_{10}S$ (S = # of species in community)
SIMP	1 - Simpson's Diversity Index	**$1 - \Sigma[n_i(n_i-1)/N(N-1)]$** n_i = # of individuals in ith sample N = Total # of species in the sample (Σn_i)

buffered 100 meters, an area representing the effective area sampled for birds. This buffered coverage was then superimposed on the forest stand coverage obtained from the Quantico Marine Corps Base and used to "clip" out the corresponding forest stand coverage. The clipped coverage for each site was then analyzed using the vector version of FRAGSTATS (UNIX based) on a SUN workstation.

Each stand of the forest stand coverage provided by Quantico was defined according to Society of American Foresters (SAF) cover type classifications (Eyre 1980) and age in years (Table 2). A new coverage was created for each site by redefining the cover type classifications into generalized habitat type classifications that incorporated age class (0-1, 2-10, 11-30, 31-70, >70 yrs.) and general habitat type (pine, hardwood, pine/hardwood mix, other) (Table 2). Age classes were defined to reflect perceived forest stand successional stages on Quantico (i.e. clearcut/seedling, sapling, pole, mature, old growth). The new coverage for each site was analyzed as before using FRAGSTATS.

FRAGSTATS generates a number of patch, class, and landscape indices (McGarigal and Marks 1995). Indices were selected based on their perceived relevance to bird species and communities as well as their relevance to the objectives of this study (Table 3). Additionally, indices were selected to eliminate comparable measurements. A number of the indices generated by FRAGSTATS are partially or completely redundant (McGarigal and Marks 1995).

Table 2. SAF cover type and generalized habitat type classifications used to define forest stands on the Quantico Marine Corps Base, VA. 1994 and 1995.

Classification	Code
SAF Cover Type	
Field/shrub - early succession	4
Native Grass	5
Managed Turf/agriculture	6
Clearcut	7
Chestnut oak	44
White oak/black oak/northern red oak	52
White oak	53
Yellow poplar	57
Yellow poplar/eastern hemlock	58
Yellow poplar/white oak/northern red oak	59
River birch/sycamore	61
Pin oak/sweetgum	65
Virginia pine/oak	78
Virginia pine	79
Loblolly pine	81
Loblolly pine/hardwood	82
Sweetgum/yellow poplar	87
Generalized Habitat Type	
Field/shrub - early succession	4
Native Grass	5
Managed Turf/agriculture	6
Clearcut (forest, age 0-1)	7
Pine, age 2-10	12
Pine, age 11-30	13
Pine, age 31-70	14
Pine, age > 70	15
Hardwood, age 2-10	22
Hardwood, age 11-30	23
Hardwood, age 31-70	24
Hardwood, age > 70	25
Pine/hdwd mix, age 2-10	32
Pine/hdwd mix, age 11-30	33
Pine/hdwd mix, age 31-70	34
Pine/hdwd mix, age > 70	35

Table 3. Habitat measures[a] used as independent variables in the development of multiple regression and logistic regression models for bird species and assemblages on the Quantico Marine Corps Base, VA. 1994 and 1995.

Mnemonic Code	Units	Description
AGE1	%	Percentage of landscape made up of 0 -10 year old forest patches.
AGE2	%	Percentage of landscape made up of 11-30 year old forest patches.
AGE3	%	Percentage of landscape made up of 31-70 year old forest patches.
AGE4	%	Percentage of landscape made up of > 70 year old forest patches.
CWED	m/ha	*Contrast-weighted edge density.* Incorporates both edge density and edge contrast in a single index.
ED	m/ha	*Edge density.* Linear measure of amount of edge per unit area.
HDWD	%	Percentage of landscape made up of hardwood patch types.
IJI	%	*Interspersion and Juxtaposition Index.* A measure of the extent to which patch types are interspersed.
MIX	%	Percentage of landscape made up of pine/hardwood mix patch types.
NCA		*Number core areas.* Number of disjunct core areas (i.e. internal patch area > 100 m from patch edge) in landscape.
PD	#/100 ha	*Patch density.* Number of habitat patches per unit area.
PINE	%	Percentage of landscape made up of pine patch types.
PRD	#/100 ha	*Patch richness density.* Number of patch types per unit area.
SHEI		*Shannon's evenness index.* A measure of the distribution of area among patch types.
TCAI	%	*Total core area index.* Percentage of landscape that is core area.

[a] See McGarigal and Marks (1995) for formulas and more detailed descriptions of habitat measures.

Data Analysis

Multicollinearity diagnostics were performed on all independent variables. Those variables accounting for the highest degree of multicollinearity were removed. Eleven independent variables were included in the SAF cover type coverage analysis: patch density (PD), edge density (ED), contrast-weighted edge density (CWED), number of core areas (NCA), total core area index (TCAI), patch richness density (PRD), Shannon's evenness index (SHEI), interspersion and juxtaposition index (IJI), percentage of landscape made up of pine (PINE), percentage of landscape made up of hardwood (HDWD), and percentage of landscape made up of pine/hardwood mix (MIX). Fifteen independent variables were included in the generalized habitat type coverage analysis. This number included all of the independent variables used in the SAF cover type coverage analysis with the addition of percentage of landscape made up of forest, age 0-10 years (AGE1), age 11-30 years (AGE2), age 31-70 years (AGE3), and age > 70 years (AGE4).

Stepwise multiple linear regression was used to determine which habitat measures were significant predictors of bird assemblage diversity and species abundance (Meyers 1986, SAS Institute 1989). Only those bird species occurring in $\geq$ 17 sites were included in the single species analysis (Appendix A). For species occurring in < 17 sites, data were converted to a binary, presence and absence response and stepwise logistic regression was performed (Hosmer and Lemeshow 1989, SAS Institute 1989). In both the stepwise multiple linear regression and the stepwise logistic regression, the significance level for a variable to enter a model was set at .25 (SLE = .25) and the significance level for a variable to stay in a model was set at .1 (SLS = .1).

RESULTS

Models Based On SAF Cover Type Classifications

Habitat Measures.--Eleven habitat variables were used in the stepwise multiple regression analysis based on SAF cover type classifications for bird assemblages and for species occurring in > 17 sites. Each variable appeared in at least one model. The same habitat variables were used in the stepwise logistic regression analysis based on SAF cover type classifications for bird species occurring in < 17 sites. Of these variables, patch density, edge density, number of core areas, and total core area index were not significant in any logistic regression models.

Patch richness density was selected most often as a significant predictor of bird species abundance, appearing in 11 of the 36 species models developed using multiple regression (Table 4) and logistic regression (Table 5). In 6 of the 11 models, species abundance was negatively related to patch richness density. The percentage of pine/hardwood forest in a landscape appeared in 6 of the 36 models and was positively related to species abundance in 5 of these. Contrast-weighted edge density appeared in 5 models and was positively related to species abundance in 3 of these. The remaining habitat measures appeared in ≤ 4 species models each. Edge density was selected least often as a significant predictor of species abundance, appearing in 1 model.

Table 4. Regression coefficients from stepwise multiple linear regression analyses for bird assemblages and species occurring in ≥ 17 sites, Quantico Marine Corps Base, VA. 1994 and 1995. Analyses were based on SAF cover type classifications.

					Independent[a]									
Dependent	PD	ED	CWED	NCA	TCAI	PRD	SHEI	IJI	PINE	HDWD	MIX	Intercept	R^2_{adj}[b]	P[c]
Assemblage Measures[d]														
TOTSPP								0.176				31.19	0.32	0.006
H			0.004									1.19	0.42	0.001
J				-0.007	0.002					-0.001		0.94	0.67	0.001
S		-0.0005	0.0006					0.0004				0.94	0.62	0.001
Neotropical migrants														
Yellow-billed cuckoo				0.094		0.043						-0.33	0.43	0.003
Eastern wood-peewee										0.008		0.11	0.24	0.017
Acadian flycatcher						-0.041			-0.013			1.52	0.44	0.003
Blue-gray gnatcatcher									-0.004			0.51	0.11	0.084
Wood thrush					0.051							0.46	0.32	0.005
Yellow-throated vireo												—[e]	—	—
Red-eyed vireo			-0.022		-0.042		-1.287					3.63	0.57	0.001
Northern parula												—	—	—
Worm-eating warbler						0.009						0.05	0.11	0.081
Ovenbird						-0.048						1.26	0.16	0.048
Louisiana waterthrush				0.019			0.099					-0.05	0.25	0.033
Hooded warbler											0.011	0.13	0.27	0.011
Scarlet tanager						-0.017						0.54	0.20	0.027
Short-distance migrants														
Mourning dove												—	—	—
Blue jay												—	—	—
American crow		-0.002	0.005									0.13	0.51	0.001
White-breasted nuthatch					0.022			-0.003			0.007	0.18	0.74	0.001
Pine warbler												—	—	—
Brown-headed cowbird	-0.006											0.22	0.28	0.009
Permanent residents														
Red-bellied woodpecker												—	—	—
Downy woodpecker						-0.013			-0.005	-0.002		0.47	0.67	0.001
Pileated woodpecker				0.016							0.002	0.01	0.38	0.007
Carolina chickadee						-0.017						0.49	0.11	0.085
Eastern tufted titmouse											0.007	0.40	0.15	0.054
Carolina wren			0.007		0.007	-0.014					0.005	-0.13	0.60	0.001

Table 4. Continued.

Northern cardinal	-0.017	0.007	0.012	0.11	0.73	0.001

[a] See Table 3. for descriptions of habitat measures.
[b] Coefficient of determination (R^2) adjusted for the number of variables in the model.
[c] P-value for full model.
[d] See Table 1. for definitions of assemblage measures.
[e] No variables met the 0.1 significance level to stay in the model.

Table 5. Estimated coefficients and predictability of models generated from stepwise logistic regression analyses for predicting the presence or absence of bird species on study sites, Quantico Marine Corps Base, VA. 1994 and 1995. Analyses were based on SAF cover type classifications.

Species	Variable[a]	Estimate	SE	Wald χ^2	P[b]	%Correct[c]	Sensitivity[d]	Specificity[e]
Neotropical Migrants								
Great-crested flycatcher	Intercept	3.317	1.394	5.661	0.017	70	87.5	0.0
	MIX	-0.130	0.070	3.431	0.064			
Prairie warbler	Intercept	5.433	3.049	3.176	0.075	60	72.7	44.4
	HDWD	-0.075	0.043	3.045	0.081			
Kentucky warbler	Intercept	-9.761	5.018	3.785	0.052	85	90.9	77.8
	IJI	0.189	0.091	4.321	0.038			
Indigo bunting	Intercept	-3.087	2.248	1.885	0.170	80	93.3	40.0
	SHEI	6.674	3.500	3.636	0.057			
Short -distance migrants								
American robin	Intercept	-4.924	2.457	4.016	0.045	65	0.0	86.7
	PRD	0.447	0.260	2.957	0.086			
Gray catbird	Intercept	-3.367	1.503	5.019	0.025	85	71.4	92.3
	PINE	0.150	0.069	4.691	0.030			
White-eyed vireo	Intercept	-4.560	2.667	2.923	0.087	80	88.9	72.7
	IJI	0.082	0.047	3.089	0.079			
Common yellowthroat	Intercept	-4.582	2.656	2.975	0.085	85	91.7	75.0
	IJI	0.099	0.050	3.997	0.046			
Rufous-sided towhee	Intercept	-2.051	1.463	1.965	0.161	65	75.0	50.0
	PRD	0.329	0.189	3.045	0.081			
Permanent Residents								
Hairy woodpecker	Intercept	4.183	2.098	3.975	0.046	65	78.6	33.3
	CWED	-0.089	0.052	2.913	0.088			

[a] See Table 3. for descriptions of habitat measures.
[b] Significance level indicating the probability of a greater value based on the Wald χ^2 statistic.
[c] Percentage of all responses that were predicted correctly.
[d] Percentage of 'event' responses that were predicted to be 'event'.
[e] Percentage of 'no event' responses that were predicted to be 'no event'.

Bird Assemblage Models.--Four measures of bird assemblage diversity and bird assemblage richness were modeled using stepwise multiple regression (Table 4). All bird assemblage models were significant ($P < 0.01$). The adjusted R^2 values ranged from 0.32 to 0.67.

The model for Pielou's equitability index yielded the highest adjusted R^2 value of 0.67 and incorporated number of core areas, total core area index and percentage of hardwood forest. The model indicated that the evenness of the distribution of individuals among species in a landscape was negatively related to the number of core areas and to the percentage of hardwood forest in a landscape, and positively related to the total core area in a landscape.

The Simpson's diversity index model yielded an adjusted R^2 value of 0.62 and incorporated edge density, contrast-weighted edge density, and the interspersion-juxtaposition index. Diversity as measured by this index was negatively related to edge per unit area in a landscape, and positively related to both the amount of contrast-weighted edge per unit area and the interspersion of patches in a landscape.

The Shannon-Wiener diversity index model yielded an adjusted R^2 value of 0.42 and incorporated a single regressor, contrast-weighted edge density. The model indicated that diversity as measured by this index was positively related to the amount of contrast-weighted edge per unit area in a landscape.

The model for the total number of species in a landscape yielded the lowest adjusted R^2 value of 0.32 and incorporated 1 regressor, the interspersion-juxtaposition index . Species richness was positively related to the interspersion of patches in a landscape.

Species Abundance Models.--*Multiple Regression Analysis*

Twenty-six bird species were modeled using stepwise multiple linear regression (Table 4). The adjusted R^2 values ranged from 0.11 (blue-gray gnatcatcher, Carolina chickadee, worm-eating warbler) to 0.74 (white-breasted nuthatch). The models developed for blue-gray gnatcatcher, worm-eating warbler, Carolina chickadee, and eastern tufted titmouse were marginally significant ($0.05<\underline{P}<0.1$). Models were not developed for 6 species (blue jay, mourning dove, northern parula, pine warbler, red-bellied woodpecker, yellow-throated vireo) because no regressors met the 0.25 significance level criterion to enter the model or the 0.1 significance level criterion to stay in the model.

Five species, eastern wood-peewee, ovenbird, Louisiana waterthrush, hooded warbler, and scarlet tanager had models that were significant at $\underline{P} < 0.05$ but not significant at the 0.01 level of significance. The adjusted R^2 value for all of these models was ≤ 0.27. The eleven species abundance models that were highly significant ($\underline{P}<0.01$) had adjusted R^2 values ≥ 0.28 (yellow-billed cuckoo, acadian flycatcher, wood thrush, red-eyed vireo, American crow, white-breasted nuthatch, brown-headed cowbird, downy woodpecker, pileated woodpecker, Carolina wren, Northern cardinal). To facilitate the discussion of important trends and patterns in the data, only those species models that were highly significant ($\underline{P}<0.01$) will be presented in detail (Table 4).

The model developed for yellow-billed cuckoos indicated that 43% of the variability in their abundance was explained by the combined effects of number of core areas and patch richness density. The relative abundance of yellow-billed cuckoos was positively related to both the number of core areas and the number of different patch types per unit area in a landscape.

The model developed for acadian flycatchers indicated that 44 % of the variability in their relative abundance was explained by the combined effects of patch richness density and the percentage of pine forest in a landscape (Table 4). Both of these variables were negatively related to acadian flycatcher abundance.

The model developed for wood thrush indicated that 32 % of the variability in their relative abundance was explained by the total core area index . Wood thrush abundance and the amount of core area in a landscape were positively related.

The red-eyed vireo model incorporated 3 regressors, the amount of contrast-weighted edge per unit area, the amount of core area, and the evenness of distribution of area among patch types, which accounted for 57 % of the variability in the relative abundance of red-eyed vireos. Red-eyed vireo abundance was negatively related to each of these.

The American crow model incorporated edge density and contrast-weighted edge density, which accounted for 51 % of the variability in their relative abundance. The abundance of American crows was negatively related to the amount of edge per unit area in a landscape and positively related to the amount of contrast-weighted edge per unit area.

The total core area index, the interspersion-juxtaposition index, and the percentage of pine/hardwood forest accounted for 74 % of the variability in white-breasted nuthatch abundance. The relative abundance of white-breasted nuthatches was positively related to both the amount of core area and the percentage of pine/hardwood forest and negatively related to the interspersion of patches in a landscape.

The brown-headed cowbird model incorporated 1 regressor, patch density, which explained 28 % of the variability in the relative abundance of brown-headed cowbirds. The relative abundance of brown-headed cowbirds was negatively related to the number of patches per unit area in a landscape.

Patch richness density, percentage of pine, and percentage of hardwood explained 67 % of the variability in the relative abundance of downy woodpeckers. Downy woodpecker abundance was negatively related to each variable.

The model developed for pileated woodpeckers indicated that 38 % of the variability in their relative abundance was explained by the combined effects of the number of core areas and the percentage of pine/hardwood forest. The relative abundance of pileated woodpeckers was positively related to both the number of core areas and the percentage of pine/hardwood forest in a landscape.

The model developed for Carolina wrens indicated that 60 % of the variability in their abundance was explained by contrast-weighted edge density, total core area index, patch richness density, and the percentage of mixed pine/hardwood forest. The relative abundance of Carolina wrens was positively related to each of these with the exception of the number of different patch types per unit area in a landscape with which it was negatively related.

The northern cardinal model incorporated patch density, patch richness density, and contrast-weighted edge density, which accounted for 73 % of the variability in northern cardinal abundance. The relative abundance of northern cardinals was negatively related to the number of patches per unit area in a landscape, and positively related to both the amount of contrast-weighted edge per unit area and the number of different patch types per unit area in a landscape.

Species Abundance Models.-- *Logistic Regression Analysis*

Ten species were successfully modeled using logistic regression (Table 5). The estimated predictability (percentage of all 'presence' and 'absence' responses predicted correctly) of these models ranged from 60 % (prairie warbler) to 85 % (Kentucky warbler, gray catbird, common yellowthroat). The estimated sensitivity (percentage of 'presence' responses predicted correctly) of these models ranged from 0.0 % (American robin) to 93.3 % (indigo bunting). Estimated specificity (percentage of 'absence' responses predicted correctly) ranged from 0.0 % (great-crested flycatcher) to 92.3 % (gray catbird). Each species model incorporated 1 regressor. Seven of the models incorporated variables that had a marginally significant ($0.05 \leq P < 0.1$) contribution to overall model predictability. Three models incorporated variables that had a significant ($P < 0.05$) contribution to overall model predictability (Kentucky warbler, gray catbird, common yellowthroat). These models will be presented in detail.

The model developed from the logistic regression analysis for the Kentucky warblers indicated that their presence in a landscape was positively related to the interspersion of patches in a landscape. Using the interspersion-juxtaposition index as a predictor, 85 % of all 'presence' and 'absence' classifications were predicted correctly, 90.9 % of 'presence' classifications were predicted correctly, and 77.8 % of 'absence' classifications were predicted correctly.

The model developed from the logistic regression analysis for gray catbirds indicated that their presence was positively related to the percentage of pine forest in a landscape. The model correctly predicted 85 % of all 'presence' and 'absence' classifications, 71.4 % of 'presence' classifications, and 92.3 % of 'absence' classifications.

The model developed from the logistic regression analysis for common yellowthroats indicated that their presence was positively related to the interspersion of patches in a landscape. Using the interspersion-juxtaposition index as a predictor, 85 % of all 'presence' and 'absence' classifications were predicted correctly, 91.7 % of 'presence' classifications were predicted correctly and 75 % of 'absence' classifications were predicted correctly.

Models Based On Generalized Habitat Type Classifications

Habitat Measures.--Fifteen habitat variables were used in the stepwise multiple regression analysis based on generalized habitat type classifications for bird assemblages and species occurring in > 17 sites. Two of these habitat variables, total core area index and the interspersion-juxtaposition index were not selected as significant predictors of species abundance in any model. The same habitat variables were used in the stepwise logistic regression analysis based on generalized habitat type classifications for bird species occurring in < 17 sites. Of these, the total core area index, Shannon's evenness index, percentage of hardwood forest, percentage of forest 0-10 years old, percentage of forest 11-30 years old, number of core areas, and the interspersion-juxtaposition index did not appear in any model.

The percentage of pine/hardwood forest and the amount of contrast-weighted edge per unit area were selected most often as significant predictors of bird species abundance, each appearing in 8 of 38 species models developed using multiple regression (Table 6) and logistic regression (Table 7). The percentage of pine/hardwood forest in a landscape was positively related to species abundance in 6 of the 8 models in which it appeared. Contrast-weighted edge density was positively related to species abundance in 6 of the 8 models in which it appeared. The number of different patch types per unit area appeared in 7 of the 38 species models and was negatively related to species abundance in 4 of these.

Of the habitat variables selected for inclusion in models, edge density, and the percentage of landscape made up of 0-10, 11-30, and 31-70 year old forest were selected least often as significant predictors of species abundance, each appearing in 2 models.

Bird Assemblage Models.--Four measures of bird assemblage diversity and bird assemblage richness were modeled using stepwise multiple regression (Table 7). All bird

Table 6. Regression coefficients from stepwise multiple linear regression analyses for bird assemblages and species occurring in ≥ 17 sites, Quantico Marine Corps Base, VA. 1994 and 1995. Analyses were based on generalized habitat type classifications.

	Independent[a]															
Dependent	PD	ED	CWED	NCA	PRD	SHEI	PINE	HDWD	MIX	AGE1	AGE2	AGE3	AGE4	Intercept	R^2_{adj}[b]	P[c]
Assemblage measures[d]																
TOTSPP					1.286									29.43	0.43	0.001
H					0.012			-0.003						1.41	0.56	0.001
J			0.0006					-0.0009						0.88	0.59	0.001
S					0.002			-0.0005						0.95	0.44	0.003
Neotropical migrants																
Yellow-billed cuckoo					0.026									0.04	0.20	0.029
Eastern wood-peewee				0.112		-0.772								0.91	0.45	0.002
Acadian flycatcher	0.041				-0.107		-0.018		-0.010					1.67	0.73	0.001
Blue-gray gnatcatcher									0.005		-0.014			0.46	0.45	0.002
Wood thrush					-0.066									1.27	0.17	0.038
Yellow-throated vireo				0.022										0.05	0.17	0.042
Red-eyed vireo			-0.013					0.014						0.96	0.41	0.004
Northern parula														—[e]	—	—
Worm-eating warbler										0.004				0.11	0.18	0.036
Ovenbird							0.014						0.011	-0.05	0.29	0.021
Louisiana waterthrush				0.024										0.02	0.26	0.013
Hooded warbler									0.011					0.13	0.27	0.011
Scarlet tanager							0.004						0.004	0.07	0.46	0.002
Short-distance migrants																
Mourning dove		0.001					-0.002							0.01	0.29	0.020
Blue jay														—	—	—
American crow			0.003	-0.019										0.08	0.56	0.001
White-breasted nuthatch				-0.027		-0.007								0.55	0.53	0.001
Pine warbler														—	—	—
Brown-headed cowbird											-0.005			0.12	0.29	0.008
Permanent residents																
Red-bellied woodpecker												-0.002		0.20	0.27	0.012
Downy woodpecker					-0.008	-0.180	-0.005	-0.005					0.001	0.68	0.77	0.001
Pileated woodpecker					-0.005				0.002					0.09	0.34	0.011
Carolina chickadee						-0.514		-0.005	0.006	-0.005				1.00	0.42	0.014
Eastern tufted titmouse			0.004	-0.060					0.010					0.46	0.51	0.002
Carolina wren			0.005						0.004					-0.01	0.46	0.002

Table 6. Continued.

Northern cardinal	0.005	-0.003	0.24	0.71	0.001

[a] See Table 3. for descriptions of habitat measures.
[b] Coefficient of determination (R^2) adjusted for the number of variables in the model.
[c] P-value for full model.
[d] See Table 1. for definitions of assemblage measures.
[e] No variables met the 0.1 significance level to stay in the model.

Table 7. Estimated coefficients and predictability of models generated from stepwise logistic regression analyses for predicting the presence or absence of bird species on study sites, Quantico Marine Corps Base, VA. 1994 and 1995. Analyses were based on generalized habitat type classifications.

Species	Variable[a]	Estimate	SE	Wald χ^2	P[b]	%Correct[c]	Sensitivity[d]	Specificity[e]
Neotropical migrants								
Ruby-throated hummingbird	Intercept	-2.305	1.536	2.253	0.133	70	83.3	50.0
	PRD	0.345	0.188	3.367	0.067			
Great-crested flycatcher	Intercept	3.323	1.397	5.661	0.017	70	87.5	0.0
	MIX	-0.130	0.070	3.441	0.064			
Prairie warbler	Intercept	-3.900	2.501	2.430	0.119	65	81.8	44.4
	ED	0.060	0.035	2.933	0.087			
Kentucky warbler	Intercept	-4.775	2.335	4.182	0.041	70	72.7	66.7
	PRD	0.624	0.285	4.773	0.029			
Yellow-breasted chat	Intercept	-3.857	1.733	4.952	0.026	80	25.0	93.8
	CWED	0.145	0.079	3.411	0.065			
Short-distance migrants								
Gray catbird	Intercept	-9.271	4.734	3.836	0.050	80	71.4	84.6
	PD	0.321	0.195	2.711	0.100			
	PINE	0.170	0.090	3.540	0.060			
White-eyed vireo	Intercept	-3.942	2.096	3.537	0.060	80	77.8	81.8
	PD	0.251	0.130	3.725	0.054			
Common yellowthroat	Intercept	-2.157	1.157	3.478	0.062	75	75.0	75.0
	AGE3	0.134	0.061	4.906	0.027			
Rufous-sided towhee	Intercept	3.327	1.876	3.144	0.076	60	75.0	37.5
	AGE4	-0.043	0.026	2.725	0.099			
Chipping sparrow	Intercept	-3.497	1.414	6.117	0.013	90	33.3	100.0
	CWED	0.099	0.060	2.747	0.098			
Field sparrow	Intercept	6.129	2.976	4.243	0.039	75	57.1	84.6
	AGE4	-0.111	0.051	4.818	0.028			
Permanent residents								
Hairy woodpecker	Intercept	2.035	0.874	5.423	0.020	65	85.7	16.7
	CWED	-0.087	0.048	3.306	0.069			

[a] See Table 3. for descriptions of habitat measures.
[b] Significance level indicating the probability of a greater value based on the Wald χ^2 statistic.
[c] Percentage of all responses that were predicted correctly.
[d] Percentage of 'event' responses that were predicted to be 'event'.
[e] Percentage of 'no event' responses that were predicted to be 'no event'.

assemblage models were significant ($P<0.01$); adjusted R^2 values ranged from 0.43 to 0.59. The model developed for Pielou's equitability index yielded the greatest adjusted R^2 value of 0.59 and indicated that contrast-weighted edge density and the percentage of hardwood forest were the greatest predictors of the evenness of the distribution of individuals among species in a landscape. Pielou's equitability index was negatively related to the percentage of hardwood forest and positively related to contrast-weighted edge density.The model for the Shannon-Wiener diversity index yielded an adjusted R^2 value of 0.56 and incorporated patch richness density and the percentage of hardwood forest. Diversity, as measured by this index, was positively related to the number of patch types per unit area in a landscape and negatively related to the amount of hardwood forest in a landscape.

The Simpson's diversity index model yielded an adjusted R^2 value of 0.44 and indicated that patch richness density and the percentage of hardwood forest in a landscape were significant predictors of diversity as measured by this index. Simpson's index was positively related to the number of different patch types per unit area and negatively related to the percentage of hardwood forest.

The model developed for the total number of species in a landscape yielded the lowest adjusted R^2 value of 0.43 and indicated that species richness was positively related to the number of different patch types per unit area in a landscape.

Species Abundance Models.--*Multiple Regression Analysis*

Twenty-six bird species were modeled using stepwise multiple linear regression (Table 6). Adjusted R^2 values ranged from 0.17(wood thrush, yellow-throated vireo) to 0.77 (downy woodpecker). All models developed were significant ($\underline{P}$<.05). Models were not developed for 3 species (blue jay, northern parula, pine warbler) because none of the regressors met the 0.25 significance level criterion to enter the model or the 0.1 significance level criterion to stay in the model.

Eleven species (yellow-billed cuckoo, wood thrush, yellow-throated vireo, worm-eating warbler, ovenbird, Louisiana waterthrush, hooded warbler, mourning dove, red-bellied woodpecker, pileated woodpecker, Carolina chickadee) had models that were moderately significant (0.01<$\underline{P}$<0.05)(Table 6). Each of these models, with the exception of those for pileated woodpecker and Carolina chickadee, had an adjusted R^2 value < 0.3.

The model developed for Carolina chickadees yielded an adjusted R^2 value of 0.42. The relative abundance of Carolina chickadees was positively related to the percentage of pine/hardwood forest in a landscape and negatively related to the evenness of the distribution of patches, the percentage of hardwood forest, and the percentage of 0 - 10 year old forest in a landscape.

The pileated woodpecker model had an adjusted R^2 value of 0.34 and incorporated 2 regressors, patch richness density with which relative abundance was negatively related and the percentage of pine/hardwood forest with which relative abundance was positively related.

Twelve of the species abundance models were highly significant (P<0.01) and had adjusted R^2 values ranging from 0.29 to 0.77 (Table 6). These models will be presented in detail.

The eastern wood-peewee model yielded an adjusted R^2 value of 0.45 and incorporated 2 regressors, the number of disjunct core areas in a landscape, with which relative abundance was positively related, and the evenness of patch distribution as measured by Shannon's evenness index, with which relative abundance was negatively related.

The acadian flycatcher model indicated that 73 % of the variability in the relative abundance of acadian flycatchers was explained by the combined effects of patch density, patch richness density, percentage of pine forest, and percentage of pine/hardwood forest. Acadian flycatcher abundance was positively related to the number of patches per unit area in a landscape, and negatively related to the number of different patch types per unit area, the percentage of pine forest, and the percentage of pine/hardwood forest in a landscape.

The model developed for blue-gray gnatcatchers indicated that 45 % of the variation in their relative abundance was explained by the combined effects of 2 regressors. Abundance was positively related to the percentage of pine/hardwood forest in a landscape and negatively related to the percentage of 11 - 30 year old forest in a landscape.

The red-eyed vireo model indicated that the combined effects of contrast-weighted edge density and the percentage of hardwood forest accounted for 41 % of the variation in the relative abundance of red-eyed vireos. Red-eyed vireo abundance was negatively related to the amount of contrast-weighted edge per unit area and positively related to the percentage of hardwood forest in a landscape.

The percentage of pine forest in a landscape and the percentage of > 70 year old forest accounted for 46 % of the variability in the relative abundance of scarlet tanagers; the relationship to both variables was positive.

The model developed for American crows indicated that 56 % of the variation in the relative abundance of American crows was explained by the combined effects of the amount of contrast-weighted edge per unit area and the number of disjunct core areas in landscape. The relative abundance of crows was positively related to contrast-weighted edge density and negatively related to the number of core areas.

The white-breasted nuthatch model indicated that 53 % of the variation in their relative abundance was explained by the combined effects of the number of disjunct core areas and the evenness of distribution of patches in landscape as measured by Shannon's evenness index. White-breasted nuthatch abundance was negatively related to both the number of core areas in a landscape and Shannon's evenness index.

The model for brown-headed cowbirds incorporated 1 regressor which accounted for 29 % of the variation in the relative abundance of brown-headed cowbirds. Brown-headed cowbird abundance was negatively related to the percentage of 11 - 30 year old forest in a landscape.

The downy woodpecker model indicated that 77 % of the variability in the relative abundance of downy woodpeckers was explained by the combined effects of 5 regressors.

The abundance of downy woodpeckers was negatively related to the number of different patch types per unit area, the evenness of patch distribution, the percentage of pine forest, and the percentage of hardwood forest in a landscape and positively related to the percentage of > 70 year old forest in a landscape.

The model for eastern tufted titmouse incorporated 3 regressors, contrast-weighted edge density, number of core areas, and percentage of pine/hardwood forest in a landscape, which accounted for 51 % of the variation in their relative abundance. The relative abundance of eastern tufted titmouse was positively related to the amount of contrast-weighted edge per unit area and the percentage of pine/hardwood forest and negatively related to the number of disjunct core areas.

The Carolina wren model indicated that 46 % of the variability in their relative abundance was explained by the combined effects of the amount of contrast-weighted edge per unit area and the percentage of mixed pine/hardwood forest in a landscape. Carolina wren abundance was positively related to both.

Northern cardinal abundance was positively related to the amount of contrast-weighted edge per unit area and negatively related to the percentage of hardwood forest. This model accounted for 71 % of the variation in northern cardinal abundance.

Species Abundance Models.--*Logistic Regression Analysis*

Twelve species were successfully modeled using logistic regression (Table 7). The estimated predictability (percentage of 'presence' and 'absence' responses predicted correctly) of these models ranged from 60 % (rufous-sided towhee) to 90 % (chipping sparrow). Sensitivity (percentage of 'presence' responses predicted correctly) ranged from 33.3 % (chipping sparrow) to 87.5 % (great-crested flycatcher). Specificity (percentage of 'absence' responses predicted correctly) for these models ranged from 0.0 % (great-crested flycatcher) to 100 % (chipping sparrow). Each model, with the exception of gray catbird, incorporated 1 regressor. The gray catbird model incorporated 2 regressors. Nine models incorporated variables that had a marginally significant ($0.05<\underline{P}<0.1$) contribution to overall model predictability (Table 7). Three models (Kentucky warbler, common yellowthroat, field sparrow) incorporated variables which contributed significantly ($P<0.05$) to overall model predictability. These models will be presented in detail.

The model developed from the logistic regression analysis of Kentucky warblers indicated that their presence was positively related to the number of different patch types per unit area in a landscape. Using patch richness density as a predictor, 70 % of all 'presence' and 'absence' responses were predicted correctly, 72.7 % of 'presence' responses were predicted correctly, and 66.7 % of 'absence' responses were predicted correctly.

Using the percentage of 31-70 year old forest as a single predictor, the common yellowthroat model correctly classified 75 % of all 'presence' and/or 'absence' responses correctly. The presence of common yellowthroats in a landscape was positively related to the percentage of 31-70 year old forest.

The model developed from the logistic regression analysis for field sparrows indicated that their presence was negatively related to the percentage of > 70 year old forest in a landscape. The model predicted 75 % of all 'presence' and 'absence' classifications, 57.1 % of 'presence' classifications, and 84.6 % of 'absence' classifications correctly.

Though contrast-weighted edge density contributed only marginally to the overall predictability (P=0.098) of the model for chipping sparrows, the chipping sparrow model yielded the greatest predictability of all the models, predicting 90 % of all 'presence' and 'absence' classifications correctly. The presence of chipping sparrows in a landscape was positively related to the amount of contrast-weighted edge per unit area. This model was less effective at predicting the 'presence' of chipping sparrows (33.3 % predicted correctly) yet highly effective at predicting their 'absence' (100 % predicted correctly).

DISCUSSION

In this study, the central question I addressed was "What are the large-scale habitat elements that influence bird assemblage diversity and bird species abundance?" Traditionally, studies dedicated to determining the habitat requirements of non-game bird species and bird assemblages have focused on the immediate area of an individual species' occurrence (Shugart and Urban 1986). Efforts generally have been targeted at measuring habitat elements characterizing the forest patch or stand within which a given species is detected (Morrison et al. 1987, Lynch and Whigham 1984). Additionally, such studies invariably examine the relationships of birds to micro- or meso-habitat elements, often incorporating some variation of the 0.04-ha circular plot vegetation sampling technique (James and Shugart 1970). It is evident, however, that birds respond to habitat elements at a much larger scale (Freemark et. al. 1993). Not only are they affected by the micro-habitat elements of the individual patches in which they occur but are also influenced by macro-level habitat elements in the surrounding landscape (Freemark and Collins 1989). This obviously has important implications for the management and conservation of birds. By examining habitat structure and composition at a landscape scale, management would move from the habitat patch to the patch mosaic. Species would no longer be managed according to micro-habitat elements of a single habitat patch or type. Rather, species would be managed over a larger area according to the macro-habitat elements of a collection of habitat patches.

A landscape mosaic is essentially defined by the patch units that compose it. Individual patch units in turn can be defined in a number of ways. Definitions may be based on very broad or very narrow habitat classifications and may incorporate patch composition, patch structure, or a combination thereof. The way in which these patches are defined influences how the relationship between a bird species or assemblage and habitat is perceived. In other words, the observed relationship between birds and habitat elements may not be equally strong for general and specific patch unit classifications. From a management perspective, the perception of how birds and habitat are related is particularly important because it affects how avian management and conservation decisions are made. Additionally, an avian management program based on relationships derived from general habitat classifications may facilitate the management of a greater number of species over a larger area and may be less costly in terms of money, time, and effort to implement. In light of this, I examined the relationship of birds to large-scale habitat elements using general and specific patch unit classifications. I first analyzed each site using SAF cover type classifications which are based solely on species composition. I then analyzed each site using a habitat classification that combined general species composition and age structure.

Assemblage Measures

SAF Cover Type Summary.--In the regression analyses based on SAF cover type classifications, higher assemblage diversity as measured by the Shannon-Wiener diversity index and the Simpson's diversity index was associated with high-contrast edges such as those between an early successional field and a mature forest. These results are not unexpected. The tendency for increased diversity and abundance of wildlife in the transition area between 2 or more habitat patches is known as the *edge effect* (Odum 1971). Edge effect is particularly evident in bird populations (Gates and Gysel 1978). The increase in bird diversity associated with edges is a result of the combined presence of bird species from adjacent habitat patches with those bird species associated with the edge area itself.

The amount of edge per unit area (not contrast-weighted) was selected as a significant predictor of diversity as measured by the Simpson's Diversity Index. Interestingly, diversity decreased with the amount of edge per unit area in a landscape.

This result points out the importance of clearly defining what we mean by "edge." I adhered to the strictest definition of edge, that is the line (or area) resulting from the union of two dissimilar habitat patches (McGarigal and Marks 1995). The majority of papers concerned with examining the effects of edge on bird species , however, define edge as the line (or area) between adjacent forested and non-forested areas. In the present study, these constituted high contrast edges and made up only a small portion of the total edge in each landscape. As far as I am aware, few avian-habitat studies have considered edges of even slightly lower contrast. I believe that by only examining the effects of high-contrast edges, researchers risk overlooking any positive or negative effects of lower contrast edges to bird species. It is important to point out however that by using such a strict definition of edge, an analysis of a GIS database with relatively specific patch type definitions may indicate the presence of more edge in a landscape than what would be present using a more traditional and less strict definition of edge. This obviously should be given careful consideration. Though my results do not allow me to make any inferences about the effects of lower contrast edges on bird species, they do highlight the importance of examining lower contrast edges and suggest an important area for further research.

Generalized Habitat Type Summary.--Under the generalized habitat type classification scheme, the percentage of hardwood forest in a landscape and the number of different patch types per unit area in a landscape were selected as significant predictors of bird assemblage diversity as measured by both the Shannon-Wiener diversity index and the Simpson's diversity index. Diversity decreased with increasing amounts of hardwood in a landscape. Hagan (1995) had similar results in a study of landbirds in an industrial forest landscape in northern Maine. He found that out of 9 broad habitat categories, mature hardwood forest supported the lowest bird diversity and the lowest bird density in a landscape. Of mid-age and mature forest categories, hardwood forest supported a lower bird diversity than both mixed softwood/hardwood and softwood forests (Hagan 1995). An additional explanation for this result may lie in the fact that overall landscape diversity declines as larger areas are composed of 1 habitat type (see following discussion on patch richness density). Given the predominance of hardwood forest on my study area, an increase in the percentage of hardwood forest in a landscape would accompany a corresponding decrease in habitat heterogeneity and thus a decrease in bird species diversity.

Diversity increased with the number of different patch types per unit area in a landscape. Many bird species, though primarily associated with a single patch type, often require a number of different patch types to meet different life requisites (Hilden 1965, Whitcomb et al. 1981). With respect to landscape composition, patch richness density is essentially a measure of habitat diversity, though it incorporates no measure of evenness or distribution. Other authors have found a positive relationship between measures of avian diversity and measures of habitat diversity as well. Johnson (1975) found that an index of habitat diversity explained 91% of the variation in the total number of bird species on study areas in the western United States. Similarly, Johnston and Odum (1956) observed an increase in bird population density with increasing plant diversity. They believed that this trend was also true of bird diversity and theorized that it was a result of an increase in the number of available niches.

Species Abundance Measures

Patch richness density, contrast-weighted edge density, and the percentage of mixed pine/hardwood forest were selected most frequently as significant predictors of individual species abundance for both the SAF cover type based analysis and the generalized habitat type based analysis. The results of the two analyses have therefore been combined and will be discussed concurrently.

Patch Richness Density.--Patch richness density was selected most frequently as a significant predictor of species abundance for both sets of analyses. The number of species whose relative abundance was significantly related to patch richness density was approximately evenly distributed between those that were negatively related and those that were positively related.

An explanation for this dichotomy may lie in each species' habitat specificity, i.e. habitat specialists and habitat generalists. Habitat specialists would be expected to select a homogenous landscape made up of 1 to a few different favorable cover types and would decline in abundance as the number of different cover types in a landscape increased. Species that are habitat generalists likely would benefit by having a greater number of different cover types in a landscape.

The Acadian flycatcher, ovenbird, scarlet tanager, downy woodpecker, Carolina chickadee, Carolina wren, wood thrush, and pileated woodpecker each showed decreasing relative abundance with increasing patch richness density. The Acadian flycatcher is a forest-interior species with a strong association with mature riparian forest (Robbins et al.

1989, Brauning 1992, Murray and Stauffer 1995). Hagan et al. (1995) ranked the habitat specificity of 72 bird species by successional stages in forested areas in Maine. Scarlet tanagers and downy woodpeckers were classified as habitat specialists, showing preferences for medium-age and mature hardwood forest. The ovenbird is a forest interior species (Whitcomb et al. 1981) that has a preference for mature, contiguous, interior forested habitat (Van Horn and Donovan 1994). The pileated woodpecker is a forest interior species (Whitcomb et al. 1981, Robbins et al. 1989) that requires large-diameter trees for nesting and roosting. It has a preference for late-successional and old growth forests (Bull and Jackson 1995).

There is some debate on the habitat specificity of the wood thrush. It is associated primarily with mature forests, however it often inhabits forest edges and suburban areas (James et al. 1984, Whitcomb et al. 1984). The habitat description by James et al. (1984) does indicate some degree of habitat specificity, however. They write, "the wood thrush is a common inhabitant of many types of (mesic) deciduous forest within its geographic range; all have a well-shaded understory that contain at least a few small trees with low, exposed branches and a fairly open forest floor with moist, decaying leafy litter. These are features of direct importance to its life history and are probably the primary determinants of the distribution and abundance of the species." The wood thrush model that incorporated patch richness density was developed based on habitat type classifications and though relatively weak ($R^2_{adj} = 0.17$), was significant ($\underline{P} < 0.05$). I believe, on my study area, the wood thrush was acting as a habitat specialist.

Though the relative abundance of Carolina chickadee and Carolina wren were negatively related to patch richness density, it may be erroneous to conclude that these species are habitat specialists. The Carolina wren clearly is a habitat generalist inhabiting an array of habitats ranging from early successional forests to mature forests of any type (Haggerty and Morton 1995). They do equally well in forest interiors and forest edges (Whitcomb et al. 1981) and are common in parks and residential areas (Buckelew and Hall 1994). Though the model developed for Carolina wrens (based on SAF cover type classifications) was quite good ($R^2_{adj} = 0.60$, $\underline{P} < .01$), the simple correlation between their relative abundance and patch richness density was very low ($\underline{r} = 0.01$). I believe that the selection of this variable was a statistical artifact resulting from the interaction of regressors in the stepwise multiple regression analysis. Complimented by one or more of the other regressors in the model (contrast-weighted edge density, total core area index, percentage of mixed pine/hardwood forest), patch richness density had a significant relationship with the relative abundance of Carolina wrens; alone, however, this relationship was negligible.

Murray and Stauffer (1995) in their study of birds in central Appalachian riparian forests classified the Carolina chickadee as a "Mature Forest Generalist." In Pennsylvania, Brauning (1992) indicated that the Carolina chickadee inhabits "wooded habitats of all kinds" and is common in suburban areas. Whitcomb et al. (1981) classified it as an interior/edge species indicating that it could occupy interior forest and forest-edge habitat equally well. The model developed for Carolina chickadee (based on SAF cover type classifications) incorporated patch richness density as the only significant predictor of its relative abundance. The model was significant at $\underline{P} < 0.1$ but not significant at $\underline{P} < 0.05$ and was very weak overall ($R^2_{adj} = 0.11$).

The yellow-billed cuckoo, worm-eating warbler, northern cardinal, American robin, rufous-sided towhee, ruby-throated hummingbird, and Kentucky warbler each showed increasing abundance with increasing patch richness density and would therefore be considered habitat generalists.

Yellow-billed cuckoos, northern cardinals, American robins, rufous-sided towhees, and ruby-throated hummingbirds are all clearly habitat generalists. Whitcomb et al. (1981) classified each of these species as interior/edge species (with the exception of American robin which was classified as a field/edge species). Interior/edge species are those that are common to forest interiors and forest edges and survive equally well in both. Further support for these classifications is given by Hagan et al. (1995) who classified the American robin as an early successional generalist and Robinson et al. (1996) who indicated that the ruby-throated hummingbird regularly occupied pine, mixed pine/hardwood, and hardwood forests as well as clearings, forest edges, gardens, and orchards. The apparent exceptions to this trend are the Kentucky warbler and the worm-eating warbler.

Habitat data for the worm-eating warbler are somewhat conflicting, however most authors concur that it is a forest-interior species requiring large areas of contiguous forest (Whitcomb et al. 1981, Lynch and Whigham 1984, Robbins et al. 1989, Brauning 1992, Buckelew and Hall 1994). In West Virginia, worm-eating warblers are associated with mature deciduous forest that lacks a dense understory (Buckelew and Hall 1994). In contrast, Brauning (1992) in Pennsylvania, indicated that its habitat is somewhat variable; however, it always includes a dense understory. Additionally, Lynch and Whigham (1984) indicated that the worm-eating warbler shows a preference for pine forest, although they conceded that their results should be interpreted with caution because of the small number of worm-eating warblers on their study area. Patch richness density was the only regressor selected for inclusion in the worm-eating warbler model. Though the simple correlation between the relative abundance of worm-eating warblers and patch richness density was significant ($\underline{r} = 0.40$, $\underline{P} < 0.05$), the overall model fit was poor ($R^2_{adj} = 0.11$, $\underline{P} = 0.08$).

The Kentucky warbler is a forest interior species associated with large areas of contiguous mature forest that have a dense understory (Lynch and Whigham 1984, Robbins et al. 1989). In Virginia, McShea et al. (1995) found that Kentucky warblers were selecting cove hardwoods with relatively dense understory within forest patches. Common to all descriptions of habitat requirements for Kentucky warbler is the presence of a dense understory. Within general habitat classifications, the distribution and abundance of a species may be determined by habitat structure and composition at smaller spatial scales (Rotenberry 1985). I postulate that Kentucky warblers were responding to habitat features at a smaller scale than that of my study. An example of habitat selection at different spatial scales is given by Steele (1992). He found that black-throated blue warblers were selecting areas with high shrub density; however, within these areas, individual territories were not located where shrub density was high. I believe that Kentucky warblers were selecting habitat with dense understory with secondary consideration to larger scale habitat characteristics. I did not take measurements on understory characteristics so I am unable to determine if there is a direct relationship between shrub density and habitat type. Given the positive response of Kentucky warblers to patch richness density, I do not believe such a relationship exists.

Percentage of Pine/Hardwood Forest.-- The percentage of mixed pine/hardwood forest was selected second most frequently as a significant predictor of species abundance and was selected more often as a significant predictor of species abundance than either pine or hardwood by themselves. For the combined results of SAF cover type classifications and generalized habitat type classifications, the percentage of pine/hardwood forest in a landscape was selected as a significant predictor of relative abundance in 9 species models and was positively related to relative species abundance in 7 of these. The percentage of hardwood forest in a landscape appeared in 6 species models and was negatively related to relative abundance in 4. The percentage of pine forest in a landscape was selected for inclusion in 7 species models and was negatively related to relative abundance in 4.

In general, it appears that a trend exists whereby higher species abundance is associated with landscapes with pine/hardwood mixed forests and species abundance declines in a landscape that is dominated by either pine or hardwood alone. As was discussed in detail earlier, there is considerable evidence that bird species diversity increases with habitat diversity. Bird species are able to meet more of their needs (shelter, food, etc.) in more diverse habitats. Mixed pine/hardwood forest habitat shares the combined characteristics of both pine and hardwood forests and is more diverse than either one by itself.

Hagan et al. (1995) in Maine found that mature hardwood stands supported the lowest diversity and abundance of bird species out of 9 broad habitat categories and medium-age mixedwood stands supported a very high species diversity. They hypothesized that the high bird diversity of mixedwood forest was a result of it being used by both softwood and hardwood specialists.

Kerpez and Stauffer (1989) determined that in avian communities of southeastern forests, pine/hardwood forests provided optimal or suitable habitat for more breeding bird species than loblolly/shortleaf pine forests. They also determined that pine/hardwood forests provided optimal or suitable habitat for a greater number of wintering bird species than either loblolly/shortleaf pine or oak/hickory forests. Johnston and Odum (1956) found that pine forests on the Georgia Piedmont supported a very low density of birds and bird density increased as the hardwood component in pine forests increased.

Temple et al. (1979) note that the avian diversity of north central and northeastern (U.S.) mixed conifer/hardwood forests is among the highest of any forest type in North America. They offer a good review of the probable reasons for the high bird diversity associated with mixed coniferous/hardwood forest types.

Contrast-weighted edge density.--The amount of contrast-weighted edge per unit area was selected the third most frequently as a significant predictor of individual species relative abundance in both the SAF cover type based analysis and the generalized habitat type based analysis. High-contrast edges are created between greatly dissimilar habitat patches. On Quantico, high-contrast edges were typically between mature forest types and non-forest types or between mature forest and early successional forest. Therefore, on Quantico, species favoring and avoiding high-contrast edges would be those species typically classified as edge and interior species, respectively. This division holds true for the results of this study.

The hairy woodpecker and red-eyed vireo decreased in relative abundance with increasing amounts of high-contrast edge per unit area in a landscape. The hairy woodpecker is a forest interior species (Whitcomb et al. 1981) with a low tolerance for forest edge (Robbins et al. 1989). Whitcomb et al. (1981) indicated that the red-eyed vireo was an interior/edge species, however Robbins et al. (1989) found an increasing probability of occurrence with increasing forest area, indicating that when available, this species selects forest interior over forest edge.

The American crow, Carolina wren, northern cardinal, eastern tufted titmouse, yellow-breasted chat, and chipping sparrow each showed increasing relative abundance with increasing amounts of high-contrast edge per unit area in a landscape. Whitcomb et al. (1981) classified American crow and yellow-breasted chat as edge species and classified the chipping sparrow as a field/edge species. Carolina wrens, northern cardinals, and eastern tufted titmice were classified as interior/edge species.

<u>Number of Core Areas</u>.--The total number of core areas in a landscape, though not selected in high frequency in either analysis, appeared in 9 models overall when the results

of the 2 analyses are considered. There was no overlap of species whose models indicated a significant relationship with the number of core areas between the 2 analyses. Relative abundance was positively related to the number of core areas in 6 of the 9 species models. Species may have been acting in 1 of 2 ways with regards to the number of core areas in a landscape. First, forest interior and forest edge species may have been responding positively and negatively, respectively to an increase in the number of core areas provided that these core areas represent mature, contiguous, forested habitat. This may or may not have been the case. Core area was defined as the internal area of a patch > 100 meters from the patch's edge. Core area therefore may include non-forested and early successional habitats. In light of this, another potential explanation for these results may be that habitat specialists and habitat generalists were responding positively and negatively, respectively to an increase in the number of core areas in a landscape. Habitat specialists would select sites with a greater number of large contiguous areas of a favorable habitat type whereas habitat generalists would avoid these sites. These results most likely are a function of a combination of both of these scenarios. For example, the Louisiana waterthrush, pileated woodpecker, and ovenbird each responded positively to an increase in the number of core areas in a landscape. Each is a forest interior species as well as a habitat specialist (Whitcomb et al. 1981, Van Horn and Donovan 1994, Bull and Jackson 1995, Robinson et al. 1995). The American crow, white-breasted nuthatch, and eastern-tufted titmouse each responded negatively to an increase in the number of core areas. Each is an edge species or interior edge species as well as a habitat generalist (Whitcomb et al. 1981, Pravosudov and Grubb 1993, Grubb and Pravosudov 1994).

Edge density.--Of the variables selected for inclusion in the individual species models from both the SAF cover type and generalized habitat type classification based analyses, edge density was selected least frequently as a significant predictor of relative abundance. This, accompanied by the result that contrast-weighted edge density was one of the most frequently selected variables, further emphasizes the importance of clearly defining edge in a habitat analysis and the importance of incorporating the concept of contrast in its definition.

SAF Cover Type vs. Generalized Habitat Type

Habitat patches were defined in 2 different ways, which formed the basis for 2 separate analyses. The first analysis was based on patches defined using SAF cover type classifications. The second was based on patches defined using generalized habitat classifications that incorporated general species composition and age structure. Both species composition and age structure have an effect on how birds select habitat (Hilden 1965, Cody 1985, Meyers and Odum 1991).

Differences in the results of the analyses based on the 2 habitat classification schemes were most obvious in the variables that were selected as significant predictors of bird assemblage diversity and species richness. Contrast-weighted edge density was selected as a significant predictor of assemblage diversity in the SAF cover type based analyses. In contrast, patch richness density and the percentage of hardwood forest in a landscape were selected as significant predictors of diversity in the generalized habitat type based analyses. Though the significant predictors of diversity were different, habitat diversity appears to be the driving force behind the selection of variables in both analyses.

Another important difference can be seen in the number of species that responded significantly to the number of core areas in each analysis. The number of species whose relative abundance was significantly related to the number of core areas in a landscape doubled in the results of the analysis based on generalized habitat types. It appears that as the total amount of core area increased from the more specific classification scheme to the more inclusive classification scheme, its importance to bird species increased. Supporting this observation is the result that the total core area index, which is a measure of the total amount of core area in a landscape, increased in 17 sites and did not change in the remaining 3 when sites were analyzed using the generalized classification scheme. This change was wholly a function of how patches were defined in each analysis. A number of factors confound the interpretation of this result, however. First, the total core area index was not selected as a significant predictor of relative abundance in any of the species models developed under the generalized classification scheme. Secondly, the number of core areas decreased in 8 sites when SAF cover type classifications were reclassified into more generalized habitat types indicating that it is not necessarily a good indicator of the total amount of core area in a landscape. Given that the total amount of core area was indeed higher on sites with patches defined using generalized habitat type classifications, the results of this study suggest that the contiguity of the core area may not be as important as the way the core area is distributed through the site.

It is important to note that 4 additional regressors (AGE1, AGE2, AGE3, AGE4) were used in the analysis based on generalized habitat type classifications. Differences in the selection of significant variables may be the result of the more general habitat classifications including the addition of age structure to the classification scheme or they may be from the addition of more regressors in the statistical analyses.

A number of similarities can be noted between the results of the 2 analyses as well, particularly with respect to the individual species models. Though the individual variables selected for inclusion in any given model were different, the variables selected as the best predictors of species abundance were the same for both. Patch richness density, the percentage of mixed pine/hardwood forest in a landscape, and contrast-weighted edge density were the 3 most frequently selected predictors of species abundance in both analyses. With respect to individual species measures, the results of the 2 analyses support each other. Both apparently can be used in determining which large-scale habitat elements influence bird assemblages and species.

Overall, it appears that habitat diversity is the most important factor influencing the large-scale selection of habitat by bird species on Quantico. The results of this study indicate that edge species and habitat generalists are selecting landscapes with greater amounts of high-contrast edge, greater density of different patch types, higher percentage of mixed pine/hardwood forest types, and fewer core areas. On the other hand, forest interior species and specialists are selecting landscapes with no edges or low-contrast edges, fewer number of patch types per unit area, and a greater number of core areas.

Management Implications

Bird species meet their needs in many different ways and require a variety of often disparate habitat conditions to do so. Habitat preferred by one species may be habitat avoided by another. As a result, no single management plan could possibly benefit all species. It is necessary to define clear management objectives as to which species are in need of management.

If a manager is managing for bird diversity, the results of this study suggest that an attempt should be made at increasing the amount of high-contrast edge in a landscape as well as managing for a greater number of mixed habitat type patches. If the management objective is to protect area-sensitive species, high-contrast edges should be avoided and large areas of contiguous mixed pine/hardwood forest should be maintained. If the objective is to manage for habitat specialists, the individual habitat requirements of each species should be identified and habitat should be managed accordingly.

Given the similarities between the two analyses, I believe that many of the common bird species occurring on Quantico can be managed according to either the SAF cover type classifications or the generalized habitat type classifications. Since the generalized habitat type classification scheme is structurally and compositionally more inclusive, a greater number of species may be managed over a broader area. Management according to this scheme therefore would be easier to implement and more parsimonious.

Limitations

One of the primary goals in this study was to examine the needs of an assemblage of birds over a landscape composed of a mosaic of habitat elements. This was accomplished through the development of models for a series of assemblage measures (species richness, species diversity, species equitability) which are in essence community models. A community is an 'aggregate of species, existing together in some definable area that provides the species specific requirements" (Balda 1975). Community models are particularly useful in management because they potentially allow a manager to manage a number of species under a single plan. There are a number of limitations to this approach, however. The first is determining which "response measure" (e.g. species richness, species diversity, species equitability, etc.) can be used appropriately to meaningfully describe the relationships between assemblages of birds and large-scale habitat configurations.

Species richness (i.e. total number of species) is greatly dependent on area as well as sampling effort and gives no information on which species are present. It therefore may be a dubious measure with respect to being used in describing relationships of bird assemblages to large-scale habitat elements. Equitability is also influenced by size of the study area (Hurlburt 1971) and by itself offers little information in describing assemblage-habitat relationships because it says nothing about the number of species present in the community or about which species are represented. Additionally, measures of evenness are biased upward unless the true total number of species is known for the community which is generally not the case (Krebs 1989). Diversity measures confound the concepts of richness and equitability and carry some of the ambiguity inherent in each. They are therefore difficult to interpret. For example, a landscape with many species and few individuals can have a diversity value equal to a landscape with a few species and many individuals. Additionally, like richness and equitability, species diversity gives no clear indication of which species are represented in a community. Diversity index values have no meaning in themselves and are only useful when compared to one another. Different diversity indices measure a community in different ways and cannot be compared to one another. This is true of the diversity measures used in this study. The Shannon-Wiener diversity index is more sensitive to rare species in a community whereas Simpson's diversity index is more sensitive to common species (Peet 1974) .

Though no conclusions were made on habitat quality *per se*, it was implied in the conclusions regarding the response of individual species and assemblages to habitat elements. The implication is that if species abundance or diversity increases with a particular habitat element, that element is "good" for the species and habitat which includes that element would be of good quality. This further complicates the task of determining which response measure can be used to describe the relationships of birds to large-scale habitat elements. Habitat, regardless of the diversity or abundance of individuals or species in it, cannot be considered high quality if species have low reproductive success (Van Horne 1983, Vickery 1992). Nesting success (Mayfield 1975) therefore would be an appropriate measure in describing the relationships of birds and large-scale habitat elements as well as an appropriate indicator of habitat quality. A number of authors have suggested supplementing abundance and diversity data with demographic data (Van Horne 1983, Vickery 1992, Feemark et al. 1993, Ralph et al. 1993). There are a number of problems with this recommendation. First, collecting data on nesting success is labor intensive and because of limited time and financial resources often comes at the expense of more general information which is also of value. A second problem in using demographic data in describing large-scale avian habitat relationships is finding an appropriate way of characterizing the reproductive success of an entire community. One possible approach is to assess the community based on an aggregation of individual species assessments. Logistically, determining the nesting success of all of the species in a community is not generally feasible, however. Also, an aggregation is not likely a suitable assessment of the overall fitness of a community as a unit in itself. Another approach is to determine the nesting success of a few representative species and link them to other species in the community or to overall species diversity. If a correlation between measures of diversity or abundance and measures of reproductive success of a few representative species could be demonstrated, these simpler measures could then be used to describe the relationships between bird assemblages and species and large-scale habitat elements.

LITERATURE CITED

Askins, R. A., J. F. Lynch, and R. Greenberg. 1990. Population declines in migratory birds in eastern North America. Current Ornithology 7:1-57.

Balda, R. P. 1975. Vegetation structure and breeding bird diversity. Pages 59-80 in D. Smith, tech coord. Proc. of the symposium on management of forest and range habitats for nongame birds. USDA For. Serv. Gen. Tech. Rep. WO-1.

Banker, M. 1994. Modeling vegetation response to succession and management. M. S. Thesis, Virginia Polytechnic Institute and State University. 148pp.

Berry, K. H. 1986. Introduction: development, testing, and application of wildlife-habitat models. Pages 3-4 in J. Verner, M. L. Morrison, and C. J. Ralph, eds. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Univ. of Wisconsin Press, Madison.

Brauning, D. W., editor. 1992. Atlas of breeding birds in Pennsylvania. University of Pittsburgh Press, Pittsburgh. 483pp.

Brittingham, M. C. and S. A. Temple. 1983. Have cowbirds caused forest songbirds to decline? BioScience 33:1:31-35.

Buckelew, A. R., and G. A. Hall. 1994. The West Virginia breeding bird atlas. University of Pittsburgh Press, Pittsburgh. 215pp.

Bull, E. L., and J. E. Jackson. 1995. Pileated woodpecker (*Dryocopus pileatus*). in A. Poole and F. Gill, eds. The birds of North America, no. 148. The Academy of Natural Sciences, Philadelphia.

Cody, M. L., editor. 1985. Habitat selection in birds. Academic Press, Inc., Orlando. 558pp.

ESRI, 1994. ArcView: the geographic information system for everyone. Version 2.1 for Windows. Environmental Systems Research Institute. Redlands, CA.

Eyre, F. H., editor. 1980. Forest cover types of the United States and Canada. Society of American Foresters. Washington, D. C. 148pp.

Faaborg, J. , M. Brittingham, T. Donovan, and J. Blake. 1993. Habitat fragmentation in the temperate zone: a perspective for managers. Pages 331-338 in D. M. Finch and

P. W. Stangel, eds. Status and Management of Neotropical Migratory Birds. USDA Forest Service Gen. Tech. Rep. RM-229.

Finch, D. M. 1991. Population ecology, habitat requirements, and conservation of neotropical migratory birds. USDA Forest Service Gen. Tech. Rep. RM-205. 26pp.

Freemark, K. E. and B. Collins. 1989. Landscape ecology of birds breeding in temperate forest fragments. Pages 443-454 in J. M Hagan and D. M. Johnston, eds. Ecology and Conservation of Neotropical Migrant Landbirds. Smithsonian Institution Press, Washington, D. C.

_______, J. R. Probst, J. B. Dunning, and S. J. Hejl. 1993. Adding a landscape ecology perspective to conservation and management planning. Pages 346-352 in D. M. Finch and P. W. Stangle, eds. Status and Management of Neotropical Migratory Birds. USDA Forest Service Gen. Tech. Rep. RM-229.

Gates, J. E. and L. W. Gysel. 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology 59:5:871-883.

Graul, W. D., and G. C. Miller. 1984. Strengthening ecosystem management approaches. Wildl. Soc. Bull. 12:282-289.

Grubb, T. C. and V. V. Pravosudov. 1994. Tufted titmouse (*Parus bicolor*). in A. Poole and F. Gill, eds. The birds of North America, no. 204. The Academy of Natural Sciences, Philadelphia.

Hagan J. M., P. S. McKinley, A. L. Meehan, and S. L. Grove. 1995. Diversity and abundance of landbirds in a northeastern industrial forest landscape. Nat. Council of the Paper Industry for Air and Stream Improvement, Tech. Bull. 705. 26pp.

Haggerty, T. M., and S. E. Morton. 1995. Carolina wren (*Thryothorus ludovicianus*). in A. Poole and F. Gill, eds. The birds of North America, no. 188. The Academy of Natural Sciences, Philadelphia.

Hilden, O. 1965. Habitat selection in birds: a review. Ann. Zool. Fenn. 2:53-75.

Hosmer, D. W. and S. Lemeshow. 1989. Applied logistic regression. John Wiley and Sons, New York. 307pp.

Hutto, R. L. 1988. Is tropical deforestation responsible for the reported declines in neotropical migrant bird populations? Am. Birds 38:10-13.

Hurlburt, S. H. 1971. The nonconcept of species diversity: a critique and alternative parameters. Ecology 52:4:577-586.

James, F. C., R. F. Johnston, N. O. Wamer, G. J. Niemi, and W. Boeklen. 1984. The grinnellian niche of the wood thrush. Am. Nat. 124:17-47.

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

Johnson, N. K. 1975. Controls of number of bird species on montane islands in the great basin. Evolution 29:545-567.

Johnston, D. W. and J. M. Hagan. 1989. An analysis of long-term breeding censuses from eastern deciduous forests. Pages 75-84 in J. M. Hagan and D. W. Johnston, eds. Ecology and conservation of Neotropical migrant landbirds. Smithsonian Institution Press, Washington.

_______.and E. P. Odum. 1956. Breeding bird populations in relation to plant succession on the piedmont of Georgia. Ecology 37:1:50-62.

Kerpez T. A. and D. F. Stauffer. 1989. Avian communities of pine-hardwood forests in the southeast: characteristics, management, and modeling. Pages 156-162 in T. A. Waldrop, ed. Proc. of pine-hardwood mixtures: a symposium on management and ecology of the type. USDA For. Serv. Gen. Tech. Rep. SE-58.

Krebs, C. J. 1989. Chapter 10: species diversity measures. Pages 328-370 in C. J Krebs, ed. Ecological methodology. Harper & Row Publishers, Inc., New York.

Laake, J. L., S. T. Buckland, D. R. Anderson, and K. P. Burnham. 1993. DISTANCE User's Guide V2.0. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins. 72pp.

Ludwig, J. A. and J. F. Reynolds. 1988. Chapter 8: diversity indices. Pages 85-103 in J. A. Ludwig and J. F. Reynolds, eds. Statistical ecology: a primer on methods and computing. John Wiley & Sons, New York.

Lynch, J. F. and D. F. Whigham. 1984. Effects of forest fragmentation on breeding bird communities in Maryland, USA. Biol. Conserv. 28:287-324.

Mayfield, H. F. 1975. Suggestions for calculating nest success. Wilson Bull. 87:456-466.

McGarigal, K. and B. J. Marks. 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. USDA For. Serv. Gen. Tech. Rep. PNW-GTR-351. 122pp.

McShea, W. J., M. V. McDonald, E. S. Morton, R. Meier, and J. H. Rappole. 1995. Long-term trends in habitat selection by Kentucky warblers. Auk 112:2:375-381.

Meyers, J. M. and E. P. Odum. 1991. Breeding bird populations of the Okefenokee swamp in Georgia: baseline for assessing future avifaunal changes. J. Field Ornithol. 62:1:53-68.

Murray, N. L. and D. F. Stauffer. 1995. Nongame bird use of habitat in central Appalachian riparian forests. J. Wildl. Manage. 59:1:78-88.

Myers, R. H. 1986. Classical and modern regression with applications. Duxbury Press, Boston. 359 pp.

Morrison, M. L., I. C. Timossi, and K. A. With. 1987. Development and testing of linear regression models predicting bird-habitat relationhips. J. Wildl. Manage. 51:1:247-253.

Morton, E. S. and R. Greenberg. 1989. The outlook for migratory songbirds: "future shock" for birders. Am. Birds 43:178-183.

Natural Resources Conservation Report. 1993. Natural Resources and Environmental Affairs Branch. Facilities Division. Marine Corps Base, Marine Corps Combat Development Command. Quantico, VA. 50pp.

Odum, E. P. 1971. Fundamentals of ecology. 3rd edition. W. B. Saunders Company, Philadelphia. 574pp.

Peet, R. K. 1974. The measurement of species diversity. Annu. Rev. Ecol. Syst. 5:285-307.

Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. J. Theoret. Biol. 13:131-144.

Pravosudov, V. V. and T. C. Grubb. 1993. White-breasted nuthatch (*Sitta carolinensis*). in A. Poole and F. Gill, eds. The birds of North America, no. 204. The Academy of Natural Sciences, Philadelphia.

Reynolds, R. T., J. M. Scott, and R. A. Nussbaum. 1980. A variable circular plot method for estimating bird numbers. Condor 82: 309-313.

Robbins, C. S. 1981. Effect of time of day on bird activity. Stud. in avian Biol. 6:275-286.

_______, D. K. Dawson, and B. A. Dowell. 1989a. Habitat area requirements of breeding forest birds of the middle Atlantic states. Wildl. Monogr. 103:1-34.

_______, J. R. Sauer, R. S. Greenberg, and S. Droege. 1989b. Population declines in North American birds that migrate to the neotropics. Proc. Natl. Acad. Sci. USA. 86:7658-7662.

Robinson, T. R., R. R. Sargent, and M. B. Sargent. 1996. Ruby-throated hummingbird (*Archilochus colubris*). in A. Poole and F. Gill, eds. The birds of North America, no. 204. The Academy of Natural Sciences, Philadelphia.

Rotenberry, J. T. 1985. The role of habitat in avian community composition: physiognomy or floristics? Oecologia 67:213-217.

SAS Institute Inc. 1989. SAS/STAT User's Guide, Version 6, Fourth Edition, Volume 2. SAS Institute Inc., Cary, NC. 846pp.

Schamberger, M. L. and L. J. O'Neil. 1986. Concepts and constraints of habitat-model testing. Pages 5-10 in J. Verner, M. L. Morrison, and C. J. Ralph, eds. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Univ. of Wisconsin Press, Madison.

Schroeder, R. L., T. T. Cable, and S. L. Haire. 1992. Wildlife species richness in shelterbelts: test of a habitat model. Wildl. Soc. Bull. 20:3:1992.

Shugart, H. H. Jr. and D. L. Urban. 1986. Modeling habitat relationships of terrestrial vertebrates: the researcher's viewpoint. Pages 425 - 429 in J. Verner, M. L. Morrison, and C. J. Ralph eds. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Univ. of Wisconsin Press, Madison.

Steele, B. B. 1992. Habitat selection by breeding black-throated blue warblers at two spatial scales. Ornis Scand. 23:33-42.

Temple S. A., M. J. Mossman, and B. Ambuel. 1979. The ecology and management of avian communities in mixed hardwood-coniferous forests. Pages 132-153 in R. M. DeGraff, tech. coord. Proc. of the workshop management of northcentral and northeastern forests for nongame birds. USDA For. Serv. Gen. Tech. Rep. NC-51.

Terborgh, J. W. 1989. Where have all the birds gone? Essays on the biology and conservation of birds that migrate to the American tropics. Princeton Univ. Press., Princeton. 207pp.

Van Horn, M. A. and T. Donovan. 1994. Ovenbird (*Seiurus aurocapillus*). in A. Poole and F. Gill, eds. The birds of North America, no. 88. The Academy of Natural Sciences, Philadelphia.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Manage. 47(4):893-901.

Verner, J. 1985a. Assessment of counting techniques. Curr. Ornith. 2:247-302.

______. and L. V. Ritter. 1985b. A comparison of transects and point counts in oak-pine woodlands of California. Condor 87:47-68.

______.1986. Summary: predicting effects of habitat patchiness and fragmentation - the researcher's viewpoint. Pages 327-329 in J. Verner, M. L. Morrison, and C. J. Ralph eds. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Univ. of Wisconsin Press, Madison.

______. 1988. Optimizing the duration of point counts for monitoring trends in bird populations. USDA For. Serv. Res. Note PSW-395. 4pp.

Vickery, P. D., M. L. Hunter, and J. V. Wells. 1992. Is density an indicator of breeding success? Auk 109:4:706-710.

Whitcomb, R. F., C. S. Robbins, J. F. Lynch, B. L. Whitcomb, M. K. Klimkiewicz, and D. Bystrak. 1981. Effects of forest fragmentation on avifauna of the eastern deciduous forest. Pages 125-206 in R. L. Burges and D. M. Sharpe, eds. Forest island dynamics in man-dominated landscapes. Springer-Verlag, New York.

Wiens, J. A., J. T. Rotenberry, and B. Van Horne. 1987. Habitat occupancy patterns of North American shrubsteppe birds: the effects of spatial scale. Oikos 48:132-147.

Wilcove, D. S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology 66:4:1211-1214.

Wilcove, D. S. and J. W. Terborgh. 1984. Patterns of population decline in birds. Am. Birds 38:10-13.

APPENDICES

Appendix A. Mnemonic codes and scientific names of bird species detected on the Quantico Marine Corps Base, VA. 1994 and 1995.

Mnemonic Code	Definition
ACFL*	acadian flycatcher (*Empidonax virescens*)
AMCR*	American crow (*Corvus brachyrhynchos*)
AMGO	American goldfinch (*Carduelis tristis*)
AMRE	American redstart (*Setophaga ruticilla*)
AMRO	American robin (*Turdus migratorius*)
BAWW	black-and-white warbler (*Mniotilta varia*)
BEKI	belted kingfisher (*Megaceryle alcyon*)
BGGN*	blue-gray gnatcatcher (*Polioptila caerulea*)
BHCO*	brown-headed cowbird (*Molothrus ater*)
BLGR	blue grosbeak (*Guiraca caerulea*)
BLJA*	blue jay (*Cyanocitta cristata*)
BRCR	brown creeper (*Certhia familiaris*)
BRTH	brown thrasher (*Toxostoma rufum*)
BTBW	black-throated blue warbler (*Dendroica caerulescens*)
BTNW	black-throated green warbler (*Dendroica virens*)
CACH*	Carolina chickadee (*Parus carolinensis*)
CARW*	Carolina wren (*Thryothorus ludovicianus*)
CAWA	Canada warbler (*Wilsonia canadesis*)
CEDW	cedar waxwing (*Bombycilla cedrorum*)
CHSP	chipping sparrow (*Spizella passerina*)
CHSW	chimney swift (*Chaetura pelagica*)
COGR	common grackle (*Quiscalus quiscalu*)
COYE	common yellowthroat (*Geothlypis trichas*)
DOWO*	downy woodpecker (*Picoides pubescens*)
EABL	eastern bluebird (*Sialia sialis*)
EAKI	eastern kingbird (*Tyrannus tyrannus*)
EAPH	eastern phoebe (*Sayornis phoebe*)
EAWP*	eastern wood peewee (*Contopus virens*)
ETTI*	eastern tufted titmouse (*Parus bicolor*)
FISP	field sparrow (*Spizella pusilla*)
GCFL	great-crested flycatcher (*Myiarchus crinitus*)
GRCA	gray catbird (*Dumetella carolinensis*)
HAWO	hairy woodpecker (*Picoides villosus*)
HETH	hermit thrush (*Catharus guttatus*)
HOWA*	hooded warbler (*Wilsonia citrina*)
HOWR	house wren (*Troglodytes aeden*)
INBU	indigo bunting (*Passerina cyanea*)
KEWA	Kentucky warbler (*Oporornis formosus*)
LOWA*	Louisiana waterthrush (*Seiurus motacilla*)
MAWA	magnolia warbler (*Dendroica magnolia*)
MAWR	marsh wren (*Cistothorus palustris*)

Appendix A. Continued.

Mnemonic Code	Definition
NOMO	northern mockingbird (*Mimus polyglottos*)
MODO*	mourning dove (*Zenaida macroura*)
NOCA*	northern cardinal (*Cardinalis cardinalis*)
NOPA*	northern parula (*Parula americana*)
OVEN*	ovenbird (*Seiurus aurocapillus*)
PIWA*	pine warbler (*Dendroica pinus*)
PIWO*	pileated woodpecker (*Dryocopus pileatus*)
PRAW	prairie warbler (*Dendroica discolor*)
PUMA	purple martin (*Progne subis*)
RBWO*	red-bellied woodpecker (*Melanerpes carolinus*)
REVI*	red-eyed vireo (*Vireo olivaceus*)
RHWO	red-headed woodpecker (*Melanerpes erythrocephalus*)
RSTO	rufous-sided towhee (*Pipilo erythrophthalmus*)
RTHU	ruby-throated hummingbird (*Archilochus colubris*)
SCTA*	scarlet tanager (*Piranga olivacea*)
SOSP	song sparrrow (*Melospiza melodia*)
SOVI	solitary vireo (*Vireo solitarius*)
SUTA	summer tanager (*Piranga rubra*)
SWTH	Swainson's thrush (*Catharus ustulatus*)
SWWA	Swainson's warbler (*Limnothlypis swainsonii*)
TRES	tree swallow (*Iridoprocne bicolor*)
UNKN	"unknown"
VEER	veery (*Catharus fuscescens*)
WBNU*	white-breasted nuthatch (*Sitta carolinensis*)
WEVI	white-eyed vireo (*Vireo griseus*)
WEWA*	worm-eating warbler (*Helmitheros vermivorus*)
WOTH*	wood thrush (*Hylocichla mustelina*)
WPWI	whip-poor-will (*Caprimulgus vociferus*)
YBCH	yellow-breasted chat (*Icteria virens*)
YBCU*	yellow-billed cuckoo (*Coccyzus americanus*)
YSFL	yellow-shafted (common) flicker (*Colaptes auratus*)
YTVI*	yellow-throated vireo (*Vireo flavifrons*)
YWAR	yellow warbler (*Dendroica petechia*)

*Species occurring in $\geq$ 17 sites.

Appendix B. Correlation coefficients (r) from correlation analyses for bird assemblages and species occurring in $\geq$ 17 sites, Quantico Marine Corps Base, VA. 1994 and 1995. Analyses were based on classifications of SAF cover types.

Dependent	PD	ED	CWED	NCA	TCAI	PRD	SHEI	IJI	PINE	HDWD	MIX	OTHER
						Independent[a]						
Assemblage Measures[b]												
TOTSPP	0.24	0.20	0.56**	-0.20	-0.24	0.58***	0.49**	0.59***	0.41*	-0.52**	-0.06	0.50**
H'	0.23	0.21	0.67***	-0.34	-0.22	0.54**	0.55**	0.64***	0.40*	-0.67***	0.10	0.61***
J	0.14	0.15	0.67***	-0.44*	-0.12	0.36	0.49**	0.56***	0.32	-0.73‡	0.26	0.65***
SIMP	0.16	0.12	0.63***	-0.23	-0.11	0.47**	0.50**	0.61***	0.41*	-0.62***	0.05	0.56**
Neotropical migrants												
Yellow-billed cuckoo	0.25	0.09	0.14	0.22	-0.27	0.48**	0.22	0.34	0.19	-0.26	0.14	0.04
Eastern wood-peewee	-0.38	-0.40*	-0.50**	0.25	0.51**	-0.41*	-0.37	-0.29	-0.51**	0.53**	0.05	-0.33
Acadian flycatcher	-0.24	-0.28	-0.33	0.23	0.31	-0.50**	-0.51**	-0.57***	-0.60***	0.54**	-0.04	-0.07
Blue-gray gnatcatcher	-0.16	-0.20	-0.15	0.17	0.24	-0.21	0.05	-0.26	-0.40	0.16	0.26	-0.02
Wood thrush	-0.57***	-0.46**	-0.21	-0.07	0.60***	-0.38	-0.22	-0.45**	-0.08	0.16	-0.12	-0.02
Yellow-throated vireo	-0.05	-0.08	-0.15	0.34	0.02	-0.12	0.19	0.16	0.01	0.11	-0.004	-0.24
Red-eyed vireo	-0.24	-0.30	-0.68‡	0.36	0.29	-0.46**	-0.57***	-0.45**	-0.48**	0.59***	0.10	-0.60***
Northern parula	0.08	0.06	0.19	0.05	0.02	-0.04	0.19	0.15	0.33	-0.24	-0.09	0.08
Worm-eating warbler	0.19	0.06	-0.02	-0.05	-0.02	0.40*	0.09	0.31	0.03	-0.09	0.16	-0.08
Ovenbird	-0.33	-0.22	-0.20	0.40*	0.10	-0.45**	0.18	-0.41*	0.15	0.14	-0.16	-0.33
Louisiana waterthrush	-0.03	0.01	-0.06	0.41	-0.20	-0.12	0.43*	0.03	0.35	-0.12	-0.11	-0.18
Hooded warbler	-0.05	-0.12	0.07	0.02	0.08	0.10	0.45**	0.18	-0.01	-0.40*	0.56**	0.09
Scarlet tanager	-0.32	-0.17	-0.29	0.30	0.24	-0.49**	-0.02	-0.33	-0.01	0.28	-0.13	-0.41*
Short-distance migrants												
Mourning dove	0.23	0.35	0.25	-0.22	-0.29	0.27	0.17	0.31	-0.10	-0.26	0.33	0.29
Blue jay	-0.30	-0.11	-0.06	0.08	0.07	-0.05	-0.02	0.08	0.23	-0.09	-0.12	-0.04
American crow	0.12	0.04	0.61***	-0.35	-0.21	0.29	0.04	0.17	0.16	-0.45**	-0.08	0.81‡
White-breasted nuthatch	-0.67***	-0.69‡	-0.55**	0.19	0.72‡	-0.60***	-0.40*	-0.67***	-0.63***	0.44*	0.28	-0.24
Pine warbler	0.06	0.01	-0.12	0.22	-0.19	-0.10	0.32	0.09	0.29	-0.14	0.06	-0.28
Brown-headed cowbird	-0.57***	-0.46**	-0.39*	0.21	0.51**	-0.48**	-0.13	-0.45**	-0.32	0.27	0.06	-0.13
Permanent residents												
Red-bellied woodpecker	-0.15	-0.08	-0.10	-0.02	0.23	-0.25	-0.16	-0.07	-0.37	0.26	0.09	-0.05
Downy woodpecker	-0.47**	-0.38*	-0.28	-0.02	0.39*	-0.59***	-0.24	-0.55**	-0.60***	0.16	0.49**	0.002
Pileated woodpecker	-0.29	-0.21	-0.47**	0.44*	0.02	-0.42*	0.02	-0.32	-0.38*	0.19	0.47**	-0.39*
Carolina chickadee	-0.12	-0.19	0.03	-0.03	0.20	-0.40	-0.17	-0.27	-0.26	-0.08	0.35	0.13
Eastern tufted titmouse	0.01	-0.03	0.30	-0.37	0.01	0.14	-0.08	0.06	-0.30	-0.22	0.44	0.39*

Appendix B. continued.

Carolina wren	0.18	0.25	0.60***	-0.41*	-0.14	0.01	0.32	0.28	0.08	-0.57***	0.30	0.66***
Northern cardinal	0.04	0.10	0.71‡	-0.37	-0.18	0.36	0.35	0.39*	0.18	-0.66***	-0.01	0.90‡

[a] See Table 3. for descriptions of habitat meaasures.
[b] See Table 1. for definitions of assemblage measures.
* $P \leq 0.10$
** $P \leq 0.05$
*** $P \leq 0.01$
‡ $P \leq 0.001$

Appendix C. Correlation coefficients (r) of correlation analyses for bird assemblages and species occurring in ≥ 17 sites, Quantico Marine Corps Base, VA. 1994 and 1995. Analyses were based on generalized habitat type classifications.

								Independent[a]								
Dependent	PD	ED	CWED	NCA	TCAI	PRD	SHEI	IJI	PINE	HDWD	MIX	OTHER	AGE1	AGE2	AGE3	AGE4
Assemblage Measures[b]																
TOTSPP	0.56***	0.52**	0.46**	0.07	-0.45**	0.68***	0.48**	0.51**	0.41*	-0.52**	-0.06	0.50**	0.24	0.11	0.38	-0.60***
H'	0.61***	0.60***	0.58***	0.05	-0.52**	0.66***	0.54**	0.56***	0.40*	-0.67***	0.10	0.61***	0.16	0.19	0.35	-0.61***
J	0.52**	0.56**	0.62***	-0.01	-0.49**	0.48**	0.47**	0.51**	0.32	-0.73‡	0.26	0.65***	0.02	0.28	0.23	-0.49**
SIMP	0.57***	0.50**	0.55**	0.10	-0.42*	0.57***	0.43*	0.55**	0.41*	-0.62***	0.05	0.56**	0.22	0.11	0.22	-0.49**
Neotropical migrants																
Yellow-billed cuckoo	0.28	0.27	0.02	0.15	-0.28	0.50**	0.18	0.29	0.20	-0.26	0.14	0.04	0.47**	0.06	0.09	-0.31
Eastern wood-peewee	-0.40*	-0.41*	-0.24	0.29	0.29	-0.49**	-0.46**	-0.25	-0.51**	0.53**	0.05	-0.33	0.12	-0.28	-0.41*	0.49**
Acadian flycatcher	-0.43*	-0.48**	0.02	0.12	0.44*	-0.66***	-0.47**	-0.46**	-0.60***	0.54**	-0.04	-0.07	-0.33	-0.43*	-0.32	0.55**
Blue-gray gnatcatcher	-0.09	-0.07	0.04	0.44*	0.002	-0.20	0.03	-0.20	-0.40*	0.16	0.26	-0.02	-0.06	-0.62***	0.001	0.22
Wood thrush	-0.40*	-0.36	-0.04	-0.16	0.34	-0.47**	-0.14	-0.34	-0.08	0.15	-0.12	-0.02	-0.22	0.001	-0.27	0.29
Yellow-throated vireo	-0.02	-0.04	-0.19	0.46**	-0.12	-0.03	0.06	0.09	0.01	0.11	-0.003	-0.24	0.04	-0.24	-0.006	0.14
Red-eyed vireo	-0.49**	-0.43*	-0.59***	-0.04	0.35	-0.50**	-0.50**	-0.39*	-0.48**	0.59***	0.10	-0.60***	-0.22	-0.02	-0.11	0.39*
Northern parula	0.06	0.05	0.08	0.21	-0.07	0.05	0.06	0.11	0.33	-0.24	-0.09	0.08	-0.01	-0.31	-0.01	0.07
Worm-eating warbler	0.26	0.26	-0.13	-0.004	-0.18	0.41*	0.17	0.30	0.03	-0.09	0.16	-0.07	0.47**	0.19	0.29	-0.45**
Louisiana waterthrush	-0.13	-0.07	-0.14	0.54**	-0.12	-0.21	0.33	-0.12	0.35	-0.12	-0.11	-0.18	0.06	-0.44*	0.07	0.12
Ovenbird	-0.35	-0.32	-0.33	-0.10	0.27	-0.41*	0.03	-0.40*	0.15	0.14	-0.16	-0.33	-0.08	-0.33	-0.23	0.41*
Hooded warbler	0.39	0.32	-0.01	0.29	-0.35	0.27	0.41*	0.21	-0.01	-0.40*	0.55**	0.09	0.24	0.01	0.15	-0.26
Scarlet tanager	-0.42*	-0.41*	-0.35	0.03	0.34	-0.52**	-0.22	-0.34	-0.01	0.28	-0.13	-0.41*	-0.03	-0.30	-0.48**	0.61***
Short-distance migrants																
Mourning dove	0.41*	0.50**	0.33	0.36	-0.49**	0.24	0.28	0.34	-0.10	-0.26	0.33	0.29	0.05	0.11	0.31	-0.37

Appendix C. Continued.

Blue jay	-0.14	-0.01	-0.08	-0.14	-0.02	-0.06	-0.08	-0.01	0.23	-0.09	-0.12	-0.03	0.11	0.20	-0.05	-0.06
American crow	0.29	0.26	$0.72^{\ddagger}$	-0.38^{*}	-0.18	0.32	0.18	0.27	0.16	-0.45^{**}	-0.08	$0.81^{\ddagger}$	-0.15	0.29	0.18	-0.45^{**}
White-breasted nuthatch	-0.56^{***}	-0.55^{**}	-0.25	-0.07	0.46^{**}	-0.61^{***}	-0.45^{**}	-0.59^{***}	-0.63^{***}	0.44^{*}	0.28	-0.24	-0.13	-0.16	-0.52^{**}	0.59^{***}
Pine warbler	-0.04	-0.09	-0.32	0.11	0.06	-0.06	0.12	-0.02	0.29	-0.14	0.06	-0.28	0.30	-0.10	-0.01	0.01
Brown-headed cowbird	-0.41^{*}	-0.33	-0.18	0.27	0.23	-0.41^{*}	-0.18	-0.43^{*}	-0.32	0.27	0.06	-0.13	0.19	-0.57^{***}	-0.12	0.24
Permanent residents																
Red-bellied woodpecker	-0.14	-0.21	0.11	0.16	0.14	-0.34	-0.32	-0.10	-0.37	0.26	0.09	-0.05	-0.15	-0.04	-0.55^{**}	0.54^{**}
Downy woodpecker	-0.40^{*}	-0.31	-0.03	-0.17	0.24	-0.53^{**}	-0.35	-0.52^{**}	-0.60^{***}	0.16	0.49^{**}	0.001	-0.31	-0.03	-0.52^{**}	0.55^{**}
Pileated woodpecker	-0.34	-0.15	-0.42^{*}	0.20	-0.04	-0.41^{*}	-0.06	-0.40^{*}	-0.38^{*}	0.18	0.47^{**}	-0.39^{*}	-0.05	-0.10	-0.16	0.33
Carolina chickadee	-0.04	-0.03	0.07	-0.29	0.10	-0.21	-0.22	-0.17	-0.25	-0.08	0.34	0.13	-0.42^{*}	-0.004	-0.07	0.19
Eastern tufted titmouse	0.28	0.34	0.37	-0.37	-0.23	0.26	0.05	0.24	-0.30	-0.22	0.44^{*}	0.39^{*}	-0.21	0.41^{*}	0.04	-0.21
Carolina wren	0.34	0.41^{*}	0.61^{***}	-0.078	-0.28	0.13	0.29	0.22	0.08	-0.56^{***}	0.30	0.66^{***}	-0.21	-0.16	0.27	-0.30
Northern cardinal	0.41^{*}	0.46^{**}	$0.79^{\ddagger}$	-0.12	-0.40^{*}	0.40^{*}	0.47^{**}	0.38	0.31	-0.66^{***}	-0.01	$0.90^{\ddagger}$	0.01	0.21	0.32	-0.62^{***}

[a] See Table 3. for descriptions of habitat measures.
[b] See Table 1. for definitions of assemblage measures.
* $P \leq 0.1$
** $P \leq 0.05$
*** $P \leq 0.01$
‡ $P \leq 0.001$

Appendix D. Summary statistics for landscape measures generated from the analysis of 20 sites based on SAF Cover Type classifications of patches, Quantico Marine Corps base, VA. 1994 and 1995.

Variable[a]	Mean	SD	Minimum	Maximum
TA	64.03	5.92	50.26	72.77
PD	21.12	5.13	9.26	29.85
ED	88.43	18.48	38.60	120.36
CWED	34.99	16.20	3.86	78.46
NCA	2.65	1.09	1.00	4.00
TCAI	5.41	5.44	0.09	24.04
PRD	7.71	3.09	1.54	13.93
SHEI	0.67	0.22	0.00	0.90
IJI	49.25	21.11	0.00	79.28
PINE	15.89	12.51	0.00	40.30
HDWD	69.04	15.62	30.45	100.00
MIX	11.49	10.11	0.00	31.40
OTHER	3.59	7.29	0.00	31.01

[a] See Table 3. for descriptions of habitat measures.

Appendix E. Summary statistics for landscape measures generated from the analysis of 20 sites based on generalized habitat type classifications of patches, Quantico Marine Corps Base, VA. 1994 and 1995.

Variable[a]	Mean	SD	Minimum	Maximum
TA	64.03	5.92	50.26	72.77
PD	14.22	6.21	1.54	25.87
ED	66.75	23.80	0.00	98.80
CWED	12.34	15.84	0.00	62.71
NCA	2.25	1.25	1.00	5.00
TCAI	13.58	14.19	0.20	58.63
PRD	8.10	3.28	1.54	13.93
SHEI	0.67	0.22	0.00	0.90
IJI	51.98	24.96	0.00	82.83
PINE	15.89	12.51	0.00	40.30
HDWD	69.04	15.62	30.45	100.00
MIX	11.49	10.12	0.00	31.40
OTHER	3.58	7.28	0.00	31.01
AGE1	3.04	8.52	0.00	36.25
AGE2	4.69	6.38	0.00	19.92
AGE3	22.70	16.41	0.00	49.19
AGE4	66.31	21.45	27.58	100.00

[a] See Table 3. for descriptions of habitat measures.

Appendix F. Bird assemblage measures[a] by site on the Quantico Marine Corps Base, VA. 1994 and 1995.

SITE	TOTSPP	H′	J	SIMP
1	43	1.38	0.85	0.94
2	51	1.45	0.85	0.95
3	37	1.32	0.84	0.94
4	36	1.22	0.78	0.91
5	36	1.26	0.81	0.93
6	32	1.24	0.83	0.92
7	42	1.36	0.84	0.94
8	46	1.37	0.82	0.94
9	42	1.33	0.82	0.94
10	51	1.47	0.86	0.96
11	31	1.20	0.81	0.92
12	39	1.31	0.82	0.93
13	42	1.37	0.84	0.94
14	32	1.25	0.83	0.92
15	35	1.23	0.80	0.92
16	34	1.19	0.78	0.90
17	35	1.26	0.81	0.92
18	41	1.37	0.85	0.94
19	42	1.31	0.81	0.93
20	50	1.50	0.88	0.96

[a] See Table 1. for descriptions of bird assemblage measures.

Appendix G. Habitat measures[a] by site based on generalized habitat type classifications, Quantico Marine Corps Base, VA. 1994 and 1995.

SITE	TA	PD	ED	CWED	NCA	TCAI	PRD	SHEI	IJI	PINE	HDWD	MIX	OTHER	AGE1	AGE2	AGE3	AGE4
1	50.26	25.87	98.80	18.28	2	4.03	13.93	0.80	74.63	18.59	62.62	16.09	2.71	0.00	12.39	26.04	58.87
2	65.00	13.85	68.29	10.04	1	14.07	12.31	0.64	57.48	19.10	74.02	5.06	1.83	13.74	7.86	15.62	60.96
3	67.34	11.88	60.18	22.86	2	20.44	5.94	0.44	47.74	0.00	83.43	13.45	3.12	0.00	0.00	1.75	95.12
4	71.04	4.22	21.23	0.00	1	39.59	2.82	0.54	0.00	12.51	87.49	0.00	0.00	0.00	0.00	12.51	87.49
5	58.06	17.22	71.80	6.68	3	12.45	6.89	0.73	66.45	36.36	63.64	0.00	0.00	0.00	0.00	20.84	79.16
6	61.79	8.09	64.42	1.29	3	8.40	4.86	0.86	42.83	40.30	49.69	10.01	0.00	0.00	0.00	40.30	59.70
7	61.08	18.01	75.69	0.00	3	3.70	11.46	0.72	67.20	14.21	62.09	23.70	0.00	0.00	11.13	17.41	71.46
8	61.77	19.43	81.87	8.88	1	13.64	11.33	0.65	57.65	29.01	65.38	4.29	1.33	0.00	1.68	43.15	53.84
9	61.61	14.61	71.28	0.29	4	7.51	11.36	0.75	56.99	16.82	68.24	14.93	0.00	36.25	1.38	21.62	40.75
10	58.93	16.97	67.24	29.37	5	4.20	8.49	0.86	82.83	27.59	61.37	0.00	11.04	4.29	0.00	40.24	44.42
11	64.78	1.54	0.00	0.00	1	58.63	1.54	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	100.00
12	53.18	3.76	46.48	0.00	3	9.79	3.76	0.90	0.00	0.00	68.60	31.40	0.00	0.00	0.00	0.00	100.00
13	67.68	19.21	88.12	1.67	3	6.48	7.39	0.79	65.16	15.74	55.47	28.79	0.00	0.00	0.00	47.05	52.95
14	70.68	11.32	61.78	2.49	1	10.63	7.07	0.55	48.70	5.99	69.85	23.80	0.36	0.00	19.92	5.99	73.73
15	66.32	15.08	51.10	24.70	1	29.31	9.05	0.39	63.30	7.22	87.73	2.01	3.05	0.00	3.77	7.25	85.92
16	66.81	10.48	69.00	1.47	3	8.83	7.48	0.64	44.33	1.38	89.43	9.19	0.00	0.00	1.38	49.19	49.43
17	68.24	17.59	82.21	23.90	4	0.79	7.33	0.69	51.41	0.00	71.19	22.33	6.48	6.48	0.00	11.51	82.01
18	62.62	19.16	87.39	26.60	1	7.22	9.58	0.90	81.74	21.92	59.36	8.38	10.35	0.00	14.98	39.00	35.67
19	70.70	15.56	69.91	5.47	2	11.65	8.49	0.58	68.04	25.41	70.75	3.49	0.35	0.00	14.38	18.10	67.17
20	72.77	20.61	98.19	62.71	1	0.20	10.99	0.88	63.18	25.64	30.45	12.89	31.01	0.00	4.98	36.43	27.58

[a] See Table 3. for descriptions of habitat measures.

Appendix H. Habitat measures[a] by site based on SAF cover type classifications, Quantico Marine Corps Base, VA. 1994 and 1995.

SITE	TA	PD	ED	CWED	NCA	TCAI	PRD	SHEI	IJI	PINE	HDWD	MIX	OTHER
1	50.26	29.85	120.36	48.74	1	0.09	13.93	0.79	66.54	18.59	62.62	16.09	2.71
2	65.00	18.46	84.81	35.07	1	10.80	10.77	0.69	59.39	19.10	74.02	5.06	1.83
3	67.34	20.79	96.04	36.58	2	8.17	7.43	0.52	52.44	0.00	83.43	13.45	3.12
4	71.04	21.12	91.30	19.75	3	0.79	4.22	0.63	25.78	12.51	87.49	0.00	0.00
5	58.06	22.39	103.34	45.56	4	0.80	5.17	0.79	42.44	36.36	63.64	0.00	0.00
6	61.79	19.42	85.46	33.15	3	4.76	4.86	0.86	53.38	40.30	49.69	10.01	0.00
7	61.08	29.47	102.10	31.18	2	2.34	9.82	0.72	57.57	14.21	62.09	23.70	0.00
8	61.77	25.90	96.95	45.65	4	1.38	9.71	0.68	60.35	29.01	65.38	4.29	1.33
9	61.61	17.86	77.87	21.51	4	5.96	11.36	0.80	62.31	16.82	68.24	14.93	0.00
10	58.92	20.37	73.56	43.70	4	4.06	8.49	0.86	79.28	27.59	61.37	0.00	11.04
11	64.78	9.26	38.60	3.86	3	24.04	1.54	0.00	0.00	0.00	100.00	0.00	0.00
12	53.18	11.28	55.03	14.80	4	9.09	3.76	0.90	0.00	0.00	68.60	31.40	0.00
13	67.68	22.16	90.96	34.85	3	6.48	4.43	0.89	66.19	15.74	55.47	28.79	0.00
14	70.68	16.98	78.22	24.80	3	3.46	5.66	0.56	43.14	5.99	69.85	23.80	0.36
15	66.32	25.63	83.17	40.17	2	7.56	10.55	0.37	43.39	7.22	87.73	2.01	3.05
16	66.81	20.96	92.94	17.14	3	4.80	7.48	0.35	30.34	1.38	89.43	9.19	0.00
17	68.24	26.38	113.93	40.82	2	0.39	7.33	0.79	56.31	0.00	71.19	22.23	6.58
18	62.62	22.36	95.59	52.30	1	7.22	9.58	0.71	68.38	21.92	59.36	8.37	10.35
19	70.70	19.80	89.68	31.70	3	5.85	8.49	0.58	60.21	25.41	70.75	3.49	0.35
20	72.77	21.99	98.71	78.46	1	0.20	9.62	0.81	57.54	25.64	30.45	12.89	31.01

[a] See Table 3. for descriptions of habitat measures.

Appendix I. Species[a] abundance indices by site for the Quantico Marine Corps Base, VA. 1994 and 1995.

SITE	ACFL	AMCR	AMGO	AMRE	AMRO	BAWW	BEKI	BGGN
1	0.784	0.022	0.000	0.000	0.000	0.045	0.000	0.534
2	0.229	0.073	0.010	0.031	0.104	0.010	0.000	0.427
3	1.343	0.000	0.000	0.000	0.000	0.000	0.000	0.552
4	.0416	0.062	0.000	0.000	0.000	0.000	0.000	0.322
5	1.031	0.021	0.000	0.000	0.000	0.010	0.000	0.458
6	0.822	0.000	0.021	0.000	0.000	0.000	0.000	0.333
7	0.708	0.083	0.021	0.073	0.010	0.052	0.000	0.354
8	0.854	0.083	0.000	0.000	0.000	0.000	0.000	0.385
9	0.718	0.031	0.000	0.000	0.010	0.000	0.000	0.385
10	1.041	0.114	0.010	0.000	0.010	0.031	0.000	0.593
11	1.614	0.021	0.000	0.000	0.000	0.010	0.000	0.541
12	1.270	0.052	0.010	0.000	0.000	0.021	0.000	0.687
13	0.833	0.041	0.000	0.000	0.000	0.052	0.000	0.625
14	0.895	0.125	0.021	0.000	0.000	0.104	0.000	0.239
15	1.291	0.177	0.010	0.000	0.000	0.041	0.000	0.437
16	1.354	0.052	0.000	0.000	0.000	0.031	0.000	0.572
17	1.500	0.010	0.021	0.000	0.000	0.000	0.000	0.520
18	0.947	0.125	0.021	0.000	0.000	0.010	0.000	0.291
19	0.822	0.083	0.000	0.000	0.000	0.041	0.010	0.239
20	0.802	0.354	0.114	0.000	0.010	0.021	0.010	0.406

Appendix I. Continued.

SITE	BHCO	BLGR	BLJA	BRCR	BRTH	BTBW	BTNW	CACH
1	0.056	0.000	0.056	0.000	0.000	0.056	0.000	0.193
2	0.166	0.000	0.156	0.010	0.000	0.062	0.031	0.322
3	0.073	0.000	0.145	0.031	0.000	0.000	0.000	0.250
4	0.073	0.000	0.104	0.000	0.000	0.021	0.021	0.239
5	0.125	0.000	0.073	0.000	0.000	0.010	0.000	0.312
6	0.083	0.000	0.187	0.000	0.000	0.000	0.010	0.281
7	0.010	0.000	0.031	0.000	0.000	0.083	0.010	0.375
8	0.031	0.000	0.093	0.021	0.000	0.010	0.010	0.468
9	0.104	0.000	0.145	0.010	0.000	0.010	0.021	0.135
10	0.104	0.010	0.062	0.000	0.021	0.104	0.010	0.197
11	0.187	0.000	0.083	0.000	0.000	0.000	0.000	0.510
12	0.166	0.000	0.093	0.000	0.000	0.000	0.010	0.458
13	0.166	0.000	0.114	0.000	0.000	0.000	0.000	0.625
14	0.041	0.000	0.145	0.000	0.000	0.000	0.000	0.468
15	0.073	0.000	0.083	0.000	0.000	0.000	0.000	0.458
16	0.145	0.000	0.093	0.010	0.000	0.010	0.031	0.312
17	0.145	0.000	0.062	0.000	0.000	0.000	0.021	0.489
18	0.031	0.000	0.041	0.000	0.000	0.000	0.000	0.291
19	0.062	0.000	0.343	0.000	0.000	0.000	0.000	0.395
20	0.083	0.000	0.156	0.000	0.010	0.000	0.000	0.510

Appendix I. Continued.

SITE	CARW	CAWA	CEDW	CHSP	CHSW	COGR	COYE	DOWO
1	0.045	0.000	0.000	0.000	0.000	0.000	0.011	0.068
2	0.104	0.000	0.010	0.031	0.000	0.000	0.021	0.093
3	0.239	0.000	0.010	0.000	0.000	0.000	0.010	0.177
4	0.052	0.000	0.000	0.000	0.000	0.000	0.000	0.083
5	0.062	0.000	0.000	0.000	0.000	0.000	0.000	0.073
6	0.083	0.000	0.000	0.000	0.000	0.000	0.021	0.093
7	0.125	0.000	0.000	0.000	0.000	0.000	0.083	0.083
8	0.052	0.000	0.000	0.000	0.000	0.000	0.104	0.073
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.031
10	0.083	0.010	0.000	0.000	0.000	0.000	0.156	0.031
11	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.250
12	0.073	0.000	0.000	0.000	0.000	0.000	0.000	0.260
13	0.343	0.000	0.000	0.000	0.000	0.000	0.010	0.197
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.229
15	0.073	0.000	0.000	0.000	0.000	0.000	0.000	0.114
16	0.021	0.000	0.000	0.000	0.000	0.000	0.093	0.083
17	0.104	0.000	0.000	0.000	0.000	0.010	0.000	0.229
18	0.125	0.000	0.000	0.021	0.000	0.000	0.187	0.062
19	0.021	0.000	0.000	0.000	0.000	0.000	0.010	0.145
20	0.427	0.000	0.000	0.041	0.052	0.000	0.750	0.166

Appendix I. Continued.

SITE	EABL	EAKI	EAPH	EAWP	ETTI	FISP	GCFL	GRCA
1	0.011	0.000	0.000	0.227	0.375	0.011	0.034	0.000
2	0.052	0.000	0.000	0.562	0.500	0.114	0.062	0.000
3	0.000	0.000	0.000	0.791	0.479	0.000	0.052	0.000
4	0.000	0.000	0.000	0.458	0.187	0.000	0.021	0.000
5	0.000	0.000	0.000	0.572	0.291	0.000	0.041	0.010
6	0.000	0.000	0.000	0.583	0.208	0.000	0.041	0.000
7	0.000	0.000	0.000	0.479	0.500	0.000	0.021	0.000
8	0.021	0.000	0.010	0.385	0.500	0.021	0.114	0.010
9	0.000	0.000	0.000	0.718	0.343	0.000	0.031	0.000
10	0.000	0.000	0.010	0.666	0.322	0.052	0.021	0.062
11	0.000	0.000	0.000	0.989	0.427	0.000	0.010	0.000
12	0.000	0.000	0.000	0.760	0.572	0.000	0.041	0.000
13	0.000	0.000	0.000	0.770	0.697	0.021	0.000	0.021
14	0.000	0.000	0.000	0.604	0.677	0.000	0.000	0.000
15	0.000	0.000	0.000	0.875	0.625	0.000	0.010	0.000
16	0.000	0.000	0.000	0.697	0.510	0.000	0.041	0.000
17	0.000	0.000	0.000	1.125	0.447	0.000	0.000	0.000
18	0.000	0.000	0.000	0.562	0.645	0.166	0.000	0.021
19	0.000	0.000	0.000	0.906	0.510	0.000	0.052	0.021
20	0.031	0.031	0.000	0.250	0.750	0.458	0.041	0.218

Appendix I. Continued.

SITE	HAWO	HETH	HOWA	HOWR	INBU	KEWA	LOWA	MAWA
1	0.034	0.011	0.340	0.000	0.159	0.045	0.125	0.000
2	0.052	0.000	0.302	0.000	0.437	0.031	0.031	0.000
3	0.031	0.000	0.145	0.000	0.000	0.021	0.083	0.000
4	0.031	0.000	0.021	0.000	0.010	0.000	0.093	0.000
5	0.021	0.000	0.197	0.000	0.010	0.000	0.114	0.021
6	0.021	0.000	0.000	0.000	0.000	0.000	0.187	0.000
7	0.010	0.000	0.468	0.000	0.062	0.197	0.031	0.000
8	0.010	0.000	0.083	0.031	0.322	0.041	0.083	0.000
9	0.010	0.010	0.489	0.000	0.062	0.010	0.083	0.000
10	0.021	0.000	0.343	0.000	0.354	0.343	0.166	0.000
11	0.041	0.000	0.166	0.000	0.000	0.000	0.041	0.000
12	0.041	0.041	0.562	0.000	0.010	0.000	0.125	0.000
13	0.000	0.010	0.812	0.000	0.156	0.010	0.010	0.000
14	0.010	0.000	0.114	0.000	0.000	0.000	0.010	0.000
15	0.000	0.021	0.135	0.000	0.114	0.000	0.010	0.000
16	0.010	0.000	0.073	0.000	0.000	0.000	0.031	0.000
17	0.000	0.073	0.052	0.000	0.021	0.041	0.093	0.000
18	0.000	0.010	0.302	0.000	0.385	0.000	0.031	0.000
19	0.000	0.000	0.187	0.000	0.145	0.010	0.031	0.000
20	0.000	0.000	0.364	0.000	0.812	0.052	0.000	0.000

Appendix I. Continued.

SITE	MAWR	MODO	NOCA	NOMO	NOPA	OVEN	PIWA	PIWO
1	0.000	0.181	0.102	0.000	0.079	0.579	0.238	0.045
2	0.000	0.010	0.135	0.021	0.239	1.145	0.229	0.031
3	0.000	0.062	0.073	0.000	0.354	0.697	0.052	0.062
4	0.000	0.000	0.010	0.000	0.052	1.333	0.510	0.073
5	0.000	0.031	0.000	0.000	0.322	1.604	0.375	0.031
6	0.000	0.083	0.010	0.000	0.260	0.875	0.427	0.083
7	0.000	0.010	0.052	0.000	0.364	0.406	0.270	0.031
8	0.000	0.000	0.093	0.000	0.229	1.073	0.083	0.083
9	0.000	0.093	0.083	0.000	0.114	0.729	0.500	0.073
10	0.000	0.093	0.239	0.021	0.250	0.645	0.177	0.041
11	0.000	0.031	0.000	0.000	0.187	0.864	0.114	0.062
12	0.000	0.041	0.114	0.000	0.114	1.583	0.177	0.135
13	0.000	0.114	0.062	0.000	0.093	1.031	0.520	0.114
14	0.000	0.093	0.031	0.000	0.021	0.625	0.291	0.114
15	0.000	0.062	0.010	0.000	0.010	0.916	0.416	0.062
16	0.000	0.145	0.000	0.000	0.021	0.541	0.021	0.093
17	0.000	0.145	0.021	0.000	0.093	0.812	0.145	0.125
18	0.000	0.052	0.250	0.000	0.062	0.916	0.114	0.021
19	0.000	0.093	0.145	0.000	0.010	0.968	0.229	0.125
20	0.021	0.125	0.510	0.010	0.197	0.531	0.166	0.031

Appendix I. Continued.

SITE	PRAW	PUMA	RBWO	REVI	RHWO	RSTO	RTHU	SCTA
1	0.011	0.000	0.136	1.238	0.000	0.022	0.011	0.261
2	0.437	0.000	0.114	0.989	0.000	0.104	0.010	0.437
3	0.135	0.000	0.302	1.760	0.000	0.000	0.000	0.614
4	0.000	0.000	0.104	1.770	0.000	0.010	0.000	0.489
5	0.000	0.000	0.156	1.302	0.000	0.000	0.010	0.656
6	0.000	0.000	0.125	2.041	0.010	0.000	0.000	0.427
7	0.010	0.000	0.135	1.635	0.000	0.000	0.000	0.395
8	0.073	0.000	0.114	1.937	0.021	0.052	0.010	0.364
9	0.000	0.000	0.093	1.562	0.000	0.010	0.010	0.395
10	0.229	0.000	0.197	1.208	0.000	0.385	0.010	0.333
11	0.000	0.021	0.218	2.375	0.000	0.000	0.000	0.458
12	0.010	0.000	0.166	1.791	0.000	0.302	0.010	0.510
13	0.177	0.000	0.093	2.010	0.010	0.395	0.010	0.385
14	0.000	0.010	0.187	2.572	0.010	0.000	0.000	0.354
15	0.000	0.000	0.114	2.156	0.000	0.031	0.010	0.343
16	0.000	0.000	0.062	2.854	0.000	0.000	0.010	0.281
17	0.000	0.000	0.281	1.927	0.021	0.000	0.000	0.395
18	0.218	0.000	0.156	1.458	0.000	0.229	0.000	0.416
19	0.031	0.010	0.166	2.041	0.000	0.010	0.010	0.437
20	0.437	0.041	0.083	0.635	0.000	0.572	0.021	0.250

Appendix I. Continued.

SITE	SOSP	SOVI	SUTA	SWTH	SWWA	TRES	UNKN	VEER
1	0.000	0.000	0.034	0.000	0.000	0.000	0.193	0.000
2	0.000	0.000	0.135	0.000	0.000	0.010	0.166	0.000
3	0.000	0.021	0.000	0.000	0.000	0.010	0.531	0.000
4	0.000	0.000	0.021	0.000	0.000	0.000	0.083	0.010
5	0.000	0.010	0.000	0.000	0.000	0.000	0.177	0.000
6	0.000	0.000	0.010	0.000	0.000	0.000	0.125	0.000
7	0.000	0.000	0.010	0.000	0.000	0.000	0.135	0.021
8	0.000	0.000	0.031	0.000	0.000	0.000	0.145	0.000
9	0.000	0.000	0.052	0.010	0.000	0.000	0.093	0.021
10	0.000	0.000	0.000	0.000	0.010	0.000	0.062	0.000
11	0.000	0.000	0.062	0.000	0.000	0.000	0.083	0.000
12	0.000	0.000	0.021	0.000	0.000	0.000	0.062	0.000
13	0.000	0.000	0.073	0.000	0.000	0.000	0.021	0.000
14	0.000	0.000	0.000	0.000	0.000	0.000	0.052	0.000
15	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000
16	0.000	0.000	0.000	0.000	0.000	0.000	0.031	0.000
17	0.000	0.000	0.000	0.000	0.000	0.000	0.093	0.000
18	0.000	0.000	0.052	0.000	0.000	0.000	0.062	0.000
19	0.000	0.000	0.010	0.000	0.000	0.000	0.041	0.000
20	0.010	0.000	0.104	0.000	0.000	0.000	0.114	0.000

Appendix I. Continued.

SITE	WBNU	WEVI	WEWA	WOTH	WPWI	YBCH	YBCU	YSFL
1	0.045	0.079	0.079	0.840	0.000	0.000	0.193	0.056
2	0.125	0.000	0.104	0.635	0.000	0.021	0.114	0.010
3	0.239	0.000	0.052	0.781	0.010	0.000	0.343	0.031
4	0.062	0.010	0.104	0.510	0.000	0.000	0.125	0.010
5	0.073	0.000	0.031	0.843	0.000	0.000	0.156	0.041
6	0.093	0.000	0.073	1.041	0.000	0.000	0.208	0.000
7	0.031	0.010	0.177	0.062	0.000	0.000	0.562	0.000
8	0.093	0.062	0.135	0.083	0.000	0.000	0.531	0.021
9	0.125	0.000	0.281	0.385	0.010	0.000	0.708	0.041
10	0.083	0.229	0.052	0.479	0.000	0.177	0.270	0.041
11	0.718	0.000	0.052	1.677	0.000	0.000	0.031	0.000
12	0.666	0.000	0.083	1.562	0.000	0.000	0.197	0.041
13	0.343	0.031	0.208	0.489	0.010	0.000	0.156	0.010
14	0.302	0.000	0.073	0.281	0.000	0.000	0.260	0.041
15	0.291	0.000	0.187	0.604	0.000	0.000	0.312	0.010
16	0.145	0.000	0.135	0.500	0.000	0.000	0.135	0.000
17	0.364	0.000	0.062	0.541	0.000	0.000	0.041	0.010
18	0.218	0.125	0.208	1.520	0.000	0.197	0.125	0.000
19	0.229	0.010	0.156	1.239	0.010	0.000	0.229	0.073
20	0.031	0.406	0.104	0.583	0.000	0.562	0.354	0.000

Appendix I. Continued.

SITE	YTVI	YWAR
1	0.056	0.000
2	0.177	0.000
3	0.166	0.000
4	0.073	0.000
5	0.145	0.000
6	0.062	0.000
7	0.145	0.000
8	0.135	0.000
9	0.062	0.000
10	0.250	0.000
11	0.083	0.000
12	0.114	0.000
13	0.114	0.000
14	0.104	0.000
15	0.010	0.000
16	0.093	0.000
17	0.114	0.000
18	0.041	0.010
19	0.052	0.000
20	0.000	0.000

[a] See Appendix A for definitions of species codes.

Appendix J. Density estimates (#/ha) calculated by site for species[a] with $\geq$ 20 observations in a given site on the Quantico Marine Corps Base, VA. 1994 and 1995.

SITE	ACFL	BGGN	BLJA	CACH	CARW	COYE	DOWO	EAWP	ETTI	FISP	GRCA	HOWA	INBU	KEWA	NOCA
1	NA[b]	NA	--[c]	--	--	--	--	NA	NA	--	--	NA	--	--	--
2	0.45	1.12	--	0.46	--	--	--	0.31	0.38	--	--	0.19	0.24	--	--
3	1.84	1.02	--	0.30	0.09	--	--	0.44	0.19	--	--	--	--	--	--
4	1.46	0.60	--	0.24	--	--	--	0.33	--	--	--	--	--	--	--
5	1.50	1.17	--	0.58	--	--	--	0.53	0.31	--	--	--	--	--	--
6	0.95	1.04	--	0.90	--	--	--	0.29	0.08	--	--	--	--	--	--
7	1.15	0.74	--	1.07	--	--	--	0.27	0.30	--	--	0.47	--	--	--
8	0.99	0.92	--	1.61	--	--	--	0.23	0.44	--	--	--	0.69	--	--
9	1.27	0.77	--	--	--	--	--	0.42	0.18	--	--	0.53	--	--	--
10	1.67	1.86	--	--	--	--	--	0.37	0.23	--	--	0.19	0.31	0.55	0.37
11	3.27	1.43	--	1.27	--	--	1.31	0.54	0.71	--	--	--	--	--	--
12	2.21	1.84	--	1.14	--	--	0.28	0.44	0.88	--	--	0.65	--	--	--
13	1.73	1.92	--	1.31	0.49	--	--	0.47	1.02	--	--	1.96	--	--	--
14	1.55	0.88	--	1.04	--	--	0.25	0.43	2.56	--	--	--	--	--	--
15	1.85	1.06	--	0.99	--	--	--	0.67	1.76	--	--	--	--	--	--
16	1.61	1.21	--	0.55	--	--	--	0.41	1.28	--	--	--	--	--	--
17	2.32	1.24	--	1.18	--	--	0.43	0.72	1.11	--	--	--	--	--	--
18	1.14	0.62	--	1.16	--	--	--	0.30	1.61	--	--	0.78	0.52	--	0.22
19	1.60	0.81	0.27	2.25	--	--	--	0.49	0.60	--	--	--	--	--	--
20	1.49	1.36	--	2.22	0.56	1.04	--	0.15	1.00	0.35	0.94	0.51	1.04	--	1.03

Appendix J. Continued.

SITE	NOPA	OVEN	PIWA	PRAW	RBWO	REVI	RSTO	SCTA	WBNU	WEVI	WEWA	WOTH	YBCH	YBCU	YTVI
1	--	NA	NA	--	--	NA	--	NA	--	--	--	NA	--	--	--
2	0.25	0.78	0.19	0.33	--	1.30	--	0.31	--	--	--	0.46	--	--	--
3	0.36	0.64	--	--	0.12	1.63	--	0.34	0.28	--	--	0.46	--	0.23	--
4	--	0.85	0.39	--	--	2.18	--	0.47	--	--	--	0.27	--	--	--
5	0.45	1.40	0.38	--	--	1.33	--	0.61	--	--	--	0.85	--	--	--
6	0.20	0.52	0.35	--	--	2.40	--	0.37	--	--	--	1.02	--	--	--
7	0.56	0.24	0.33	--	--	2.08	--	0.32	--	--	--	--	--	0.38	--
8	0.23	0.83	--	--	--	2.53	--	0.35	--	--	--	--	--	0.45	--
9	--	0.67	0.51	--	--	1.53	--	0.30	--	--	0.16	0.23	--	0.36	--
10	0.35	0.52	--	0.26	--	1.60	0.51	0.21	--	0.76	--	0.27	--	0.16	0.33
11	--	0.90	--	--	0.19	2.39	--	0.35	1.25	--	--	1.93	--	--	--
12	--	1.79	--	--	--	3.48	0.59	0.68	1.06	--	--	1.88	--	--	--
13	--	0.79	0.54	--	--	3.55	1.03	0.35	0.41	--	0.16	0.36	--	--	--
14	--	0.81	0.17	--	--	3.53	--	0.45	0.41	--	--	0.29	--	0.22	--
15	--	0.69	0.48	--	--	3.95	--	0.29	0.53	--	--	0.50	--	0.42	--
16	--	0.38	--	--	--	3.77	--	0.20	--	--	--	0.33	--	--	--
17	--	0.96	--	--	0.11	2.64	--	0.52	0.43	--	--	0.50	--	--	--
18	--	0.64	--	0.12	--	1.93	0.30	0.23	0.27	--	0.24	0.91	--	--	--
19	--	0.82	0.15	--	--	3.48	--	0.32	0.40	--	--	1.16	--	0.20	--
20	--	0.65	--	0.41	--	0.93	0.77	0.19	--	0.56	--	0.60	0.97	0.36	--

[a] See Appendix A for definitions of species codes.

[b] $\geq$ 20 observations were made of this species but a density estimate is not available.

[c] Species with < 20 observations. No density estimate is available.

Appendix K. Edge-contrast[a] weights[b] for combinations of patches defined using SAF cover type classifications[c] on study sites, Quantico Marine Corps Base, VA. 1994 and 1995.

0	0.1		0.3	0.6	1.0	
7,6	79,81	81,81	79,58	79,44	4,79	7,44
	44,52	82,82	79,78	79,52	4,81	7,52
	44,53	87,87	79,82	79,53	4,44	7,53
	44,57	4,5	81,58	79,57	4,52	7,57
	44,59	4,6	81,78	79,59	4,53	7,58
	44,61	5,6	81,82	79,61	4,57	7,59
	44,65	4,4	44,58	79,65	4,59	7,61
	44,87	5,5	44,78	79,87	4,61	7,65
	52,53	6,6	44,82	81,44	4,65	7,78
	52,57	7,4	52,58	81,52	4,87	7,79
	52,59	7,5	52,78	81,53	4,58	7,81
	52,61		52,82	81,57	4,78	7,82
	52,65		53,58	81,59	4,82	7,87
	52,87		53,78	81,61	5,79	
	53,57		53,82	81,65	5,81	
	53,59		57,58	81,87	5,44	
	53,61		57,78		5,52	
	53,65		57,82		5,53	
	53,87		59,58		5,57	
	57,59		59,78		5,59	
	57,61		59,82		5,61	
	57,65		61,58		5,65	
	57,87		61,78		5,87	
	59,61		61,82		5,58	
	59,65		65,58		5,78	
	59,87		65,78		5,82	
	61,65		65,82		6,79	
	61,87		87,58		6,81	
	65,87		87,78		6,44	
	58,78		87,82		6,52	
	58,82				6,53	
	78,82				6,57	
	44,44				6,59	
	52,52				6,61	
	53,53				6,65	
	57,57				6,87	
	58,58				6,58	
	59,59				6,78	
	61,61				6,82	
	65,65					
	78,78					
	79,79					

[a] Contrast is a measure of the degree of dissimilarity between adjacent patches.
[b] 0 = minimum contrast, 1 = maximum contrast.
[c] See Table 2 for definitions of patch classifications.

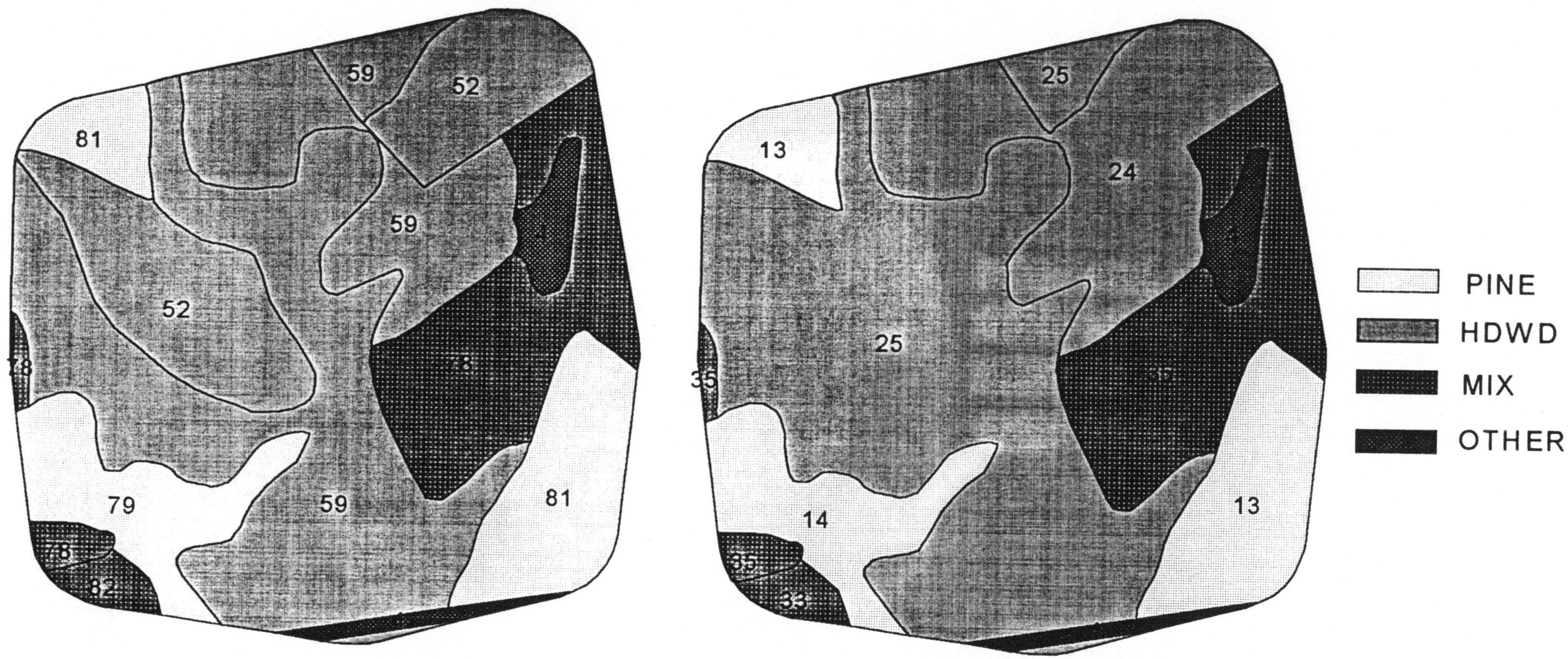
Appendix L. Edge-contrast[a] weights[b] for combinations of patches defined using generalized habitat type classifications[c] on study sites, Quantico Marine Corps Base, VA. 1994 and 1995.

0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0
6,7	12,32	12,13	12,33	12,14	12,34	12,15	12,35	12,25	4,15
	13,33	22,23	13,32	22,24	13,35	22,25	15,32	15,22	4,25
	14,34	32,33	13,34	32,34	14,32	32,35	22,35	4,14	4,35
	15,35	13,14	14,33	13,15	15,33	12,24	25,32	4,24	5,15
	22,32	23,24	14,35	23,25	22,34	13,25		4,34	5,25
	23,33	33,34	15,34	33,35	23,35	14,22		5,14	5,35
	24,34	14,15	22,33	12,23	24,32	15,23		5,24	6,15
	25,35	24,25	23,32	13,22	25,33	4,13		5,34	6,25
	4,5	34,35	23,34	13,24		4,23		6,14	6,35
	4,6	12,22	24,33	14,23		4,33		6,24	7,15
	4,7	13,23	24,35	14,25		5,13		6,34	7,25
	5,6	14,24	25,34	15,24		5,23		7,14	7,35
	5,7	15,25		4,12		5,33		7,24	
				4,22		6,13		7,34	
				4,32		6,23			
				5,12		6,33			
				5,22		7,13			
				5,32		7,23			
				6,12		7,33			
				6,22					
				6,32					
				7,12					
				7,22					
				7,32					

[a] Contrast is a measure of the degree of dissimilarity between adjacent patches.
[b] 0 = minimum contrast, 1 = maximum contrast.
[c] See Table 2 for definitions of patch classifications.

Appendix M. Study sites[a] with patches defined using SAF cover types[b] and generalized habitat types[b], Quantico Marine Corps Base, VA. 1994-1995.

Site 1

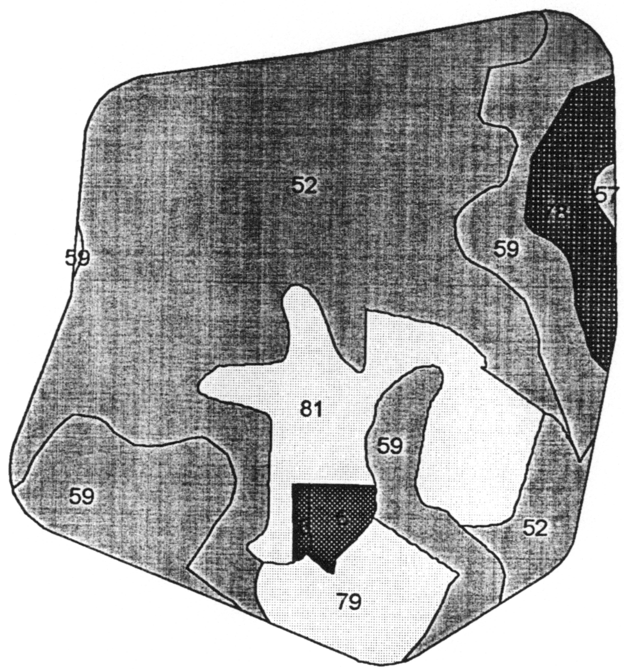


SAF Cover Type

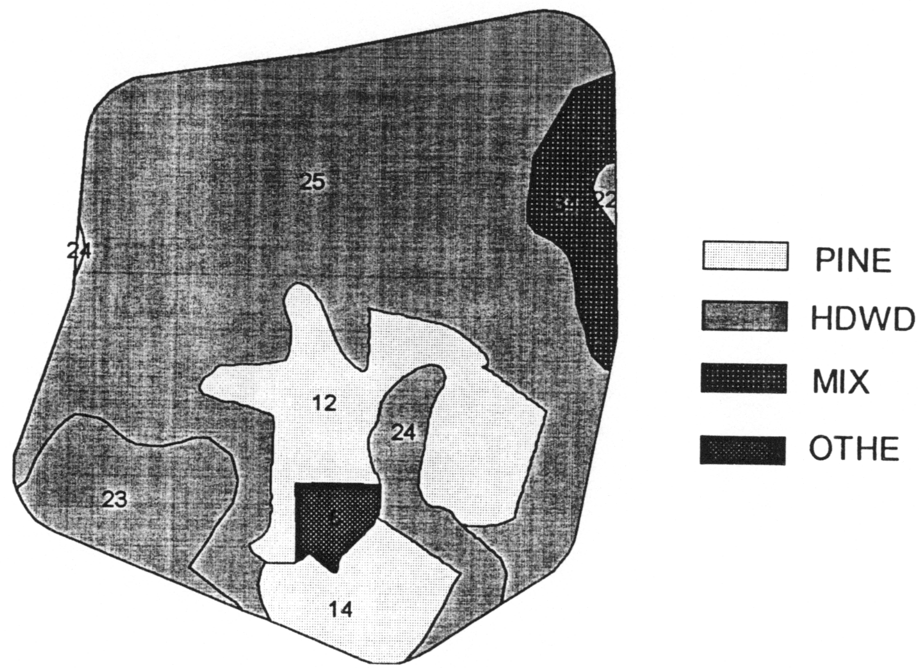
Generalized Habitat Type

Appendix M. Continued.

Site 2



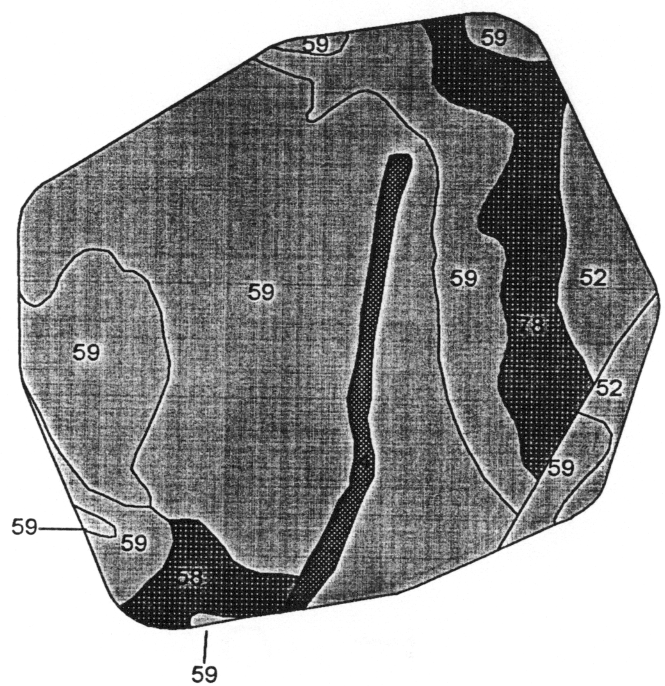
SAF Cover Type



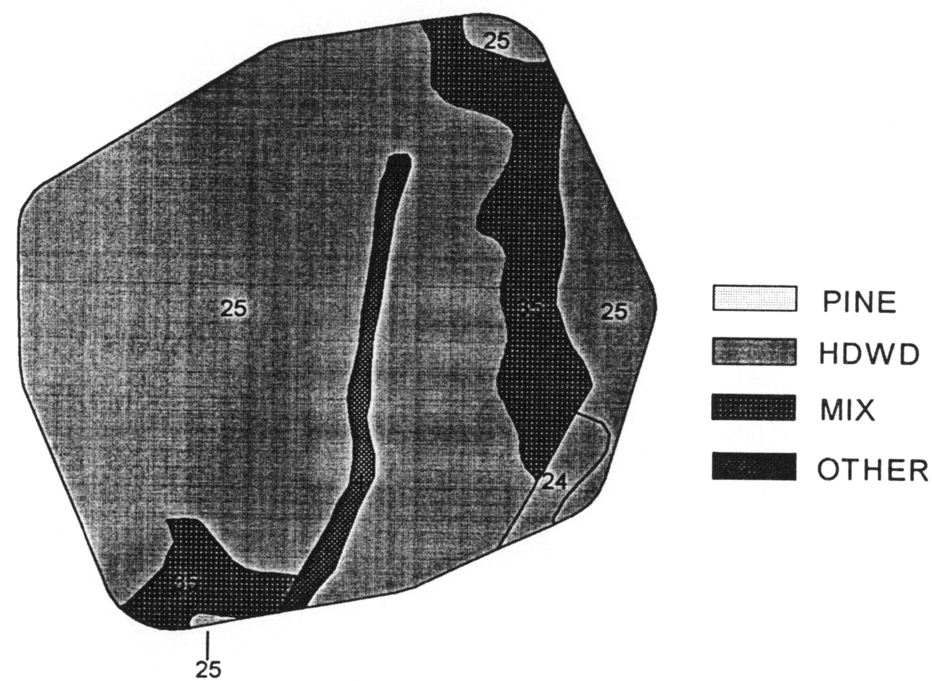
Generalized Habitat Type

Appendix M. Continued.

Site 3



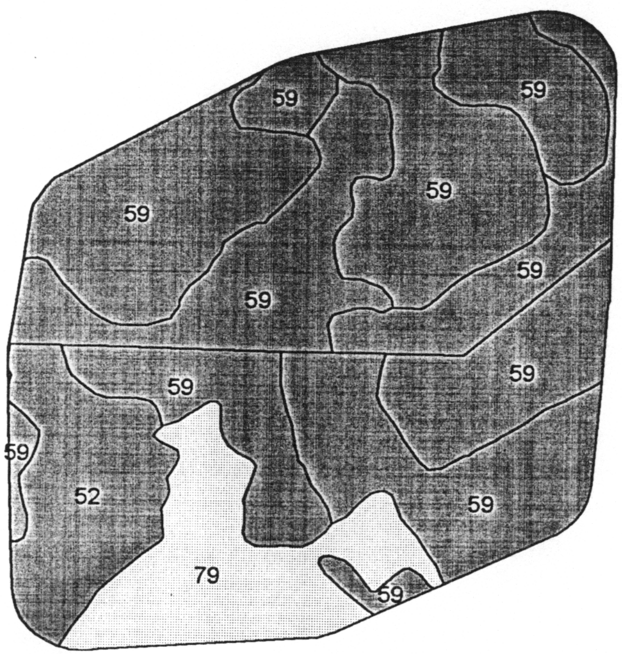
SAF Cover Type



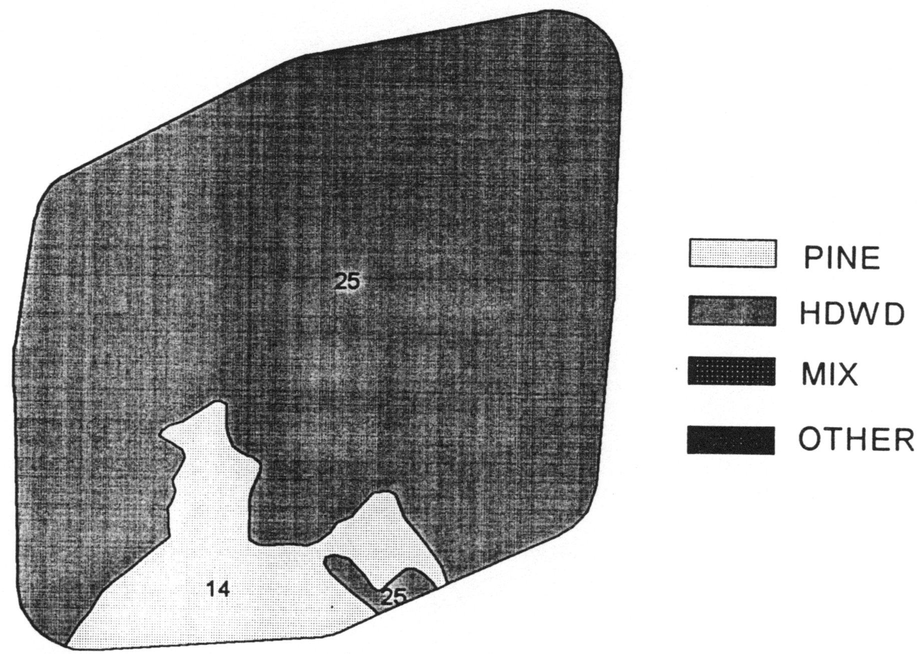
Generalized Habitat Type

Appendix M. Continued.

Site 4



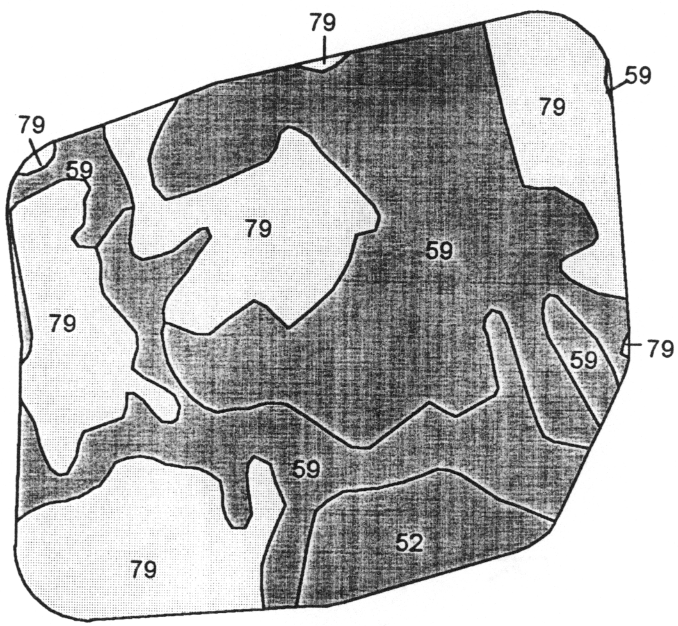
SAF Cover Type



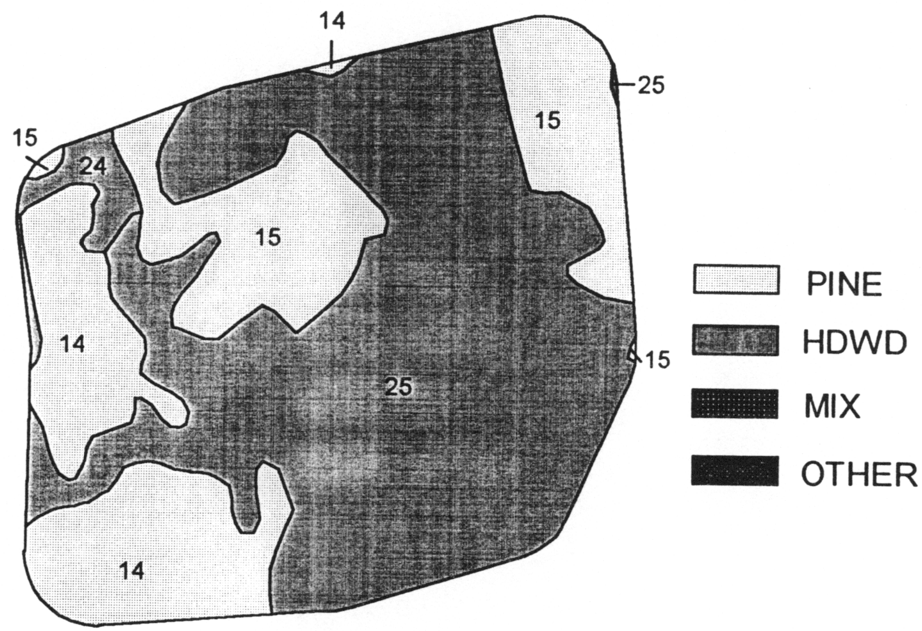
Generalized Habitat Type

Appendix M. Continued

Site 5

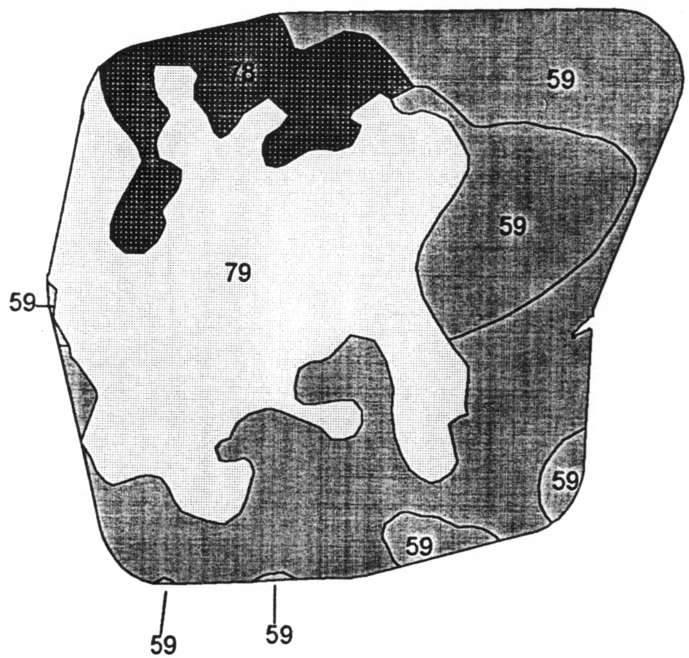


SAF Cover Type

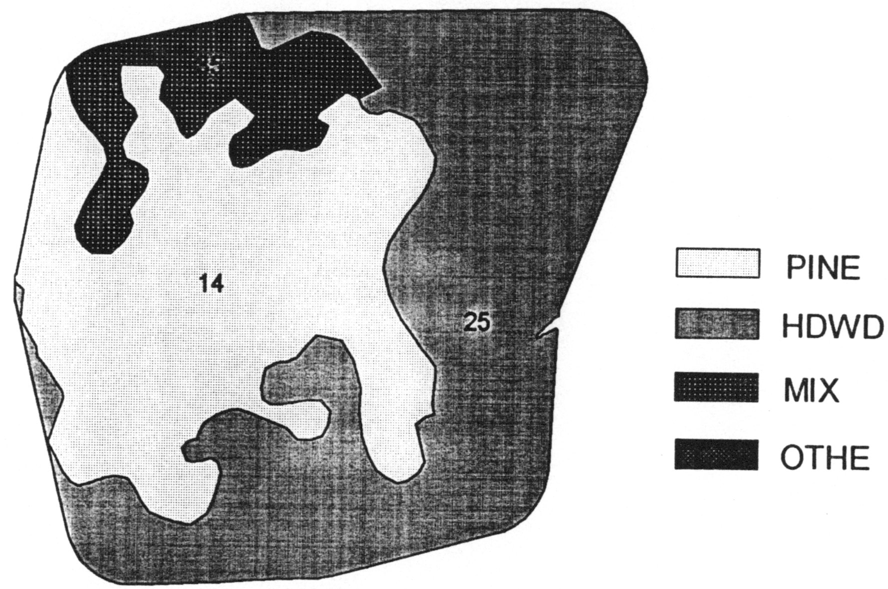


Generalized Habitat Type

<u>Site 6</u>

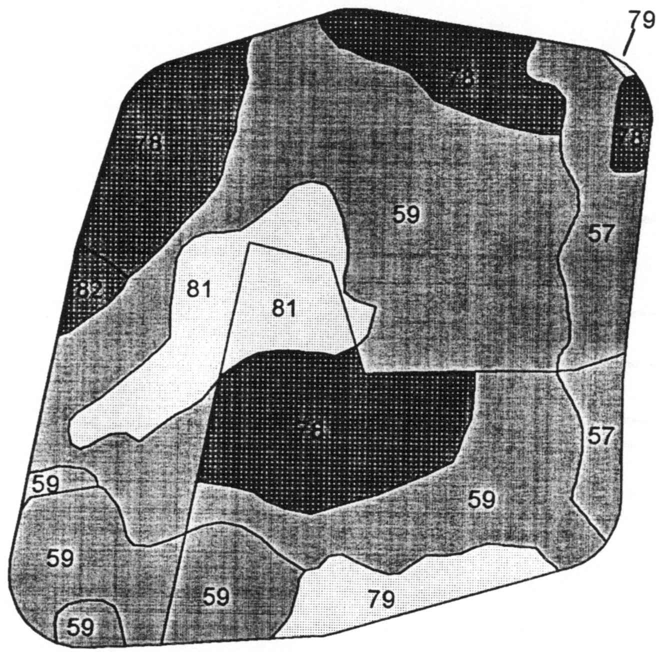


SAF Cover Type

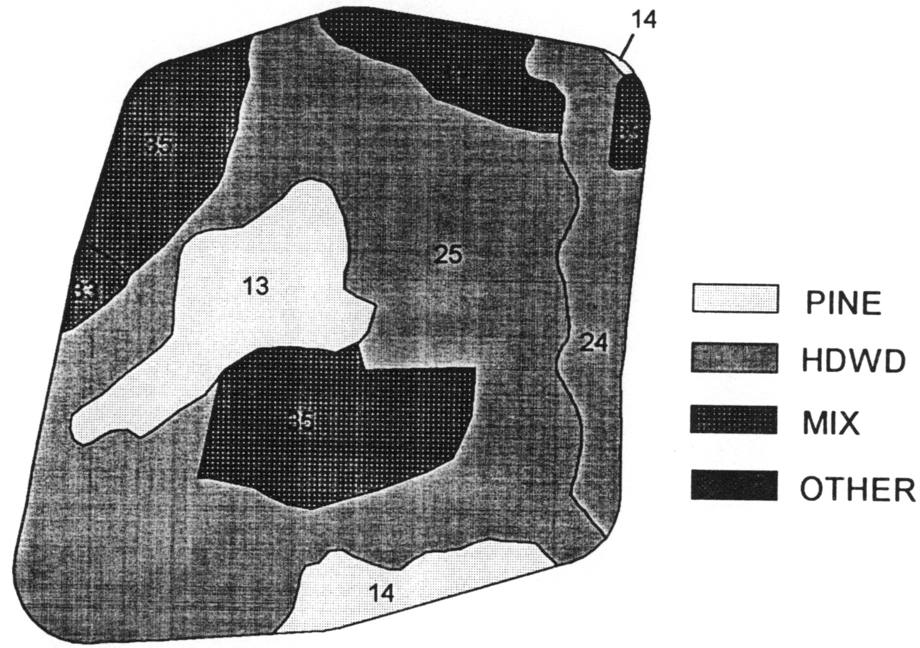


Generalized Habitat Type

Site 7

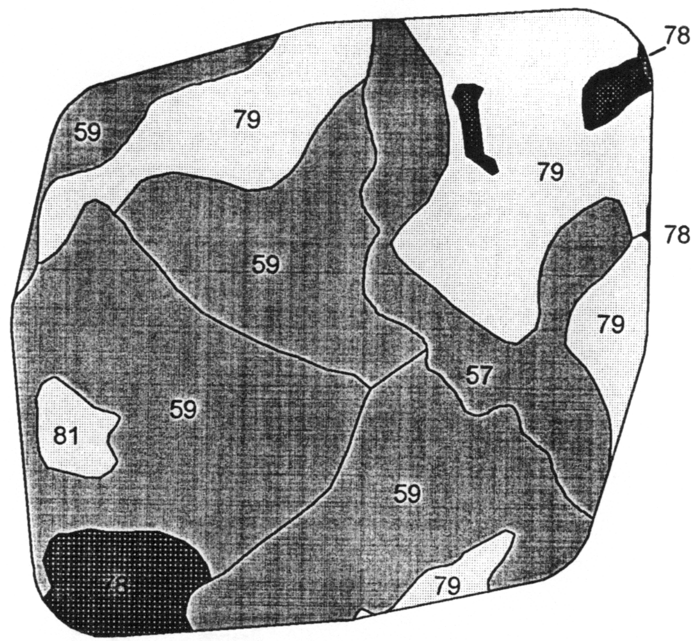


SAF Cover Type

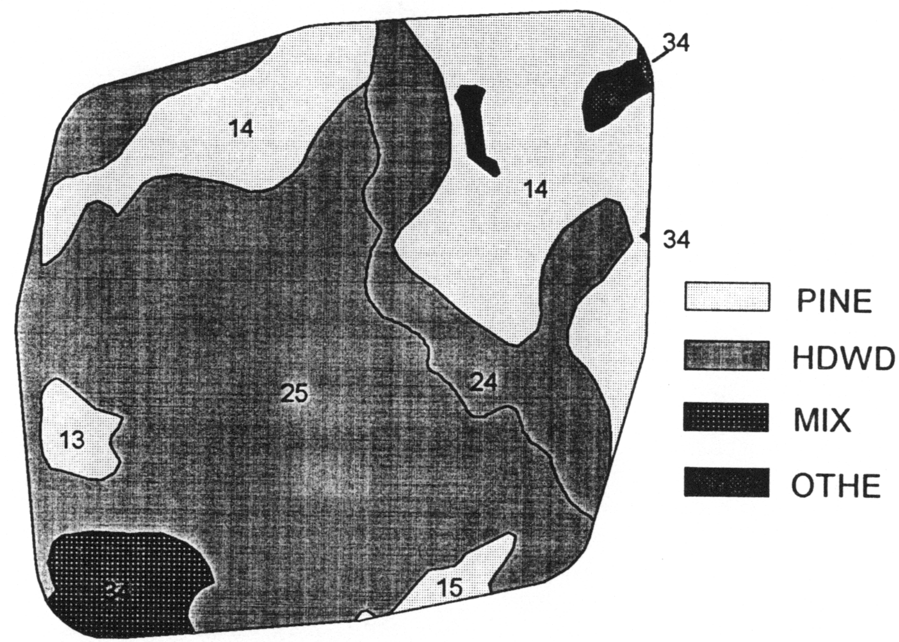


Generalized Habitat Type

Site 8



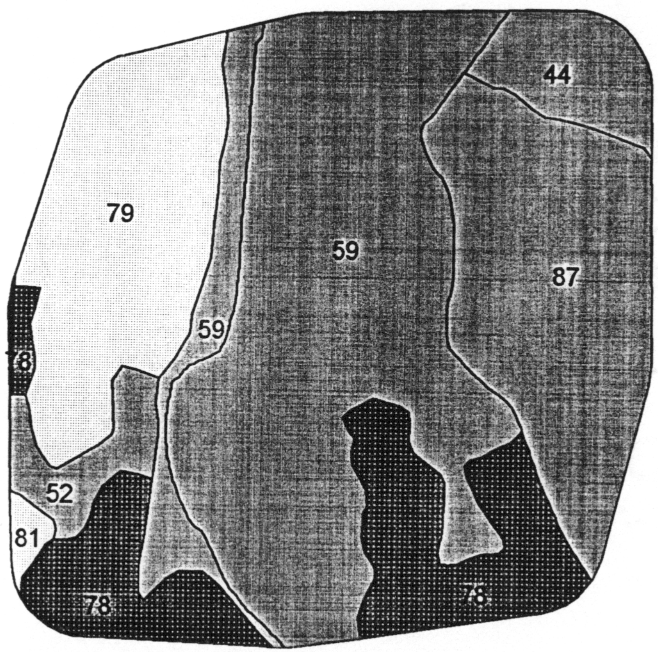
SAF Cover Type



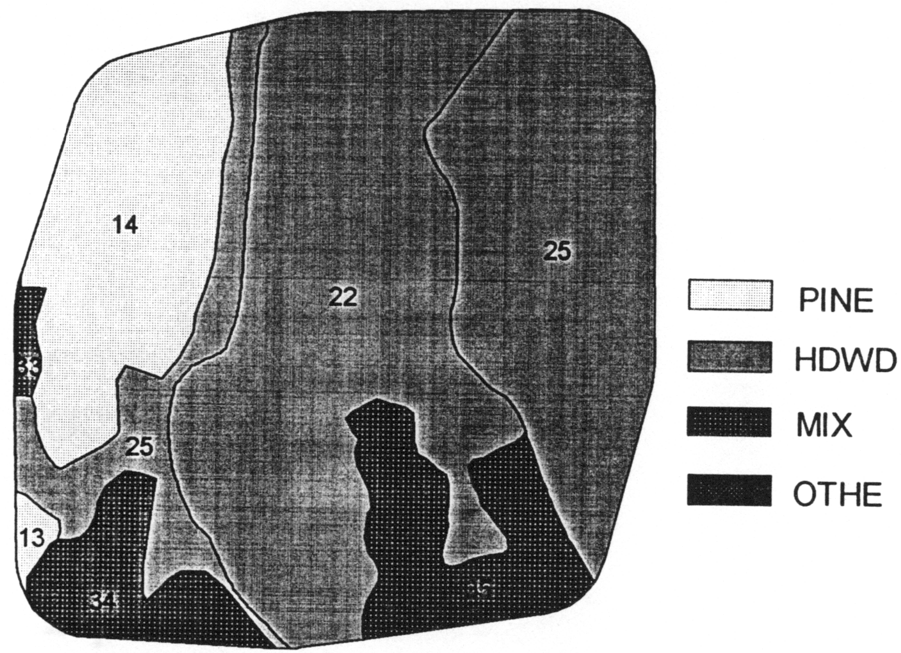
Generalized Habitat Type

Appendix M. Continued.

Site 9



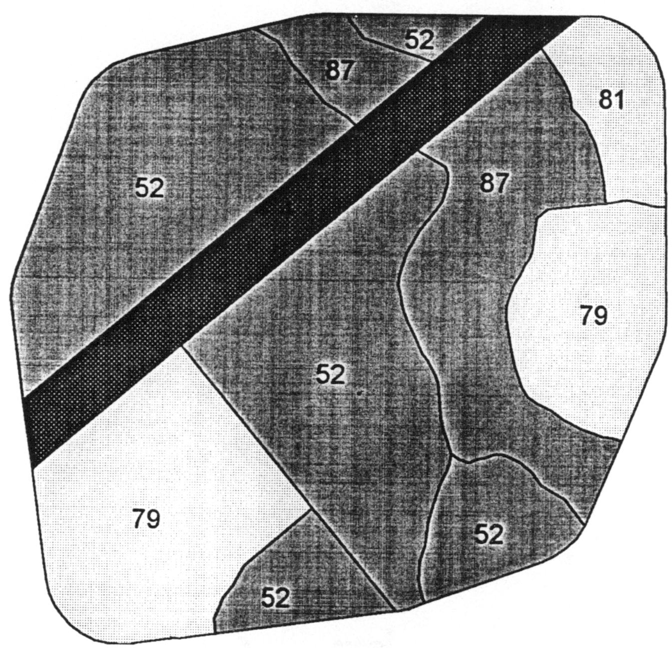
SAF Cover Type



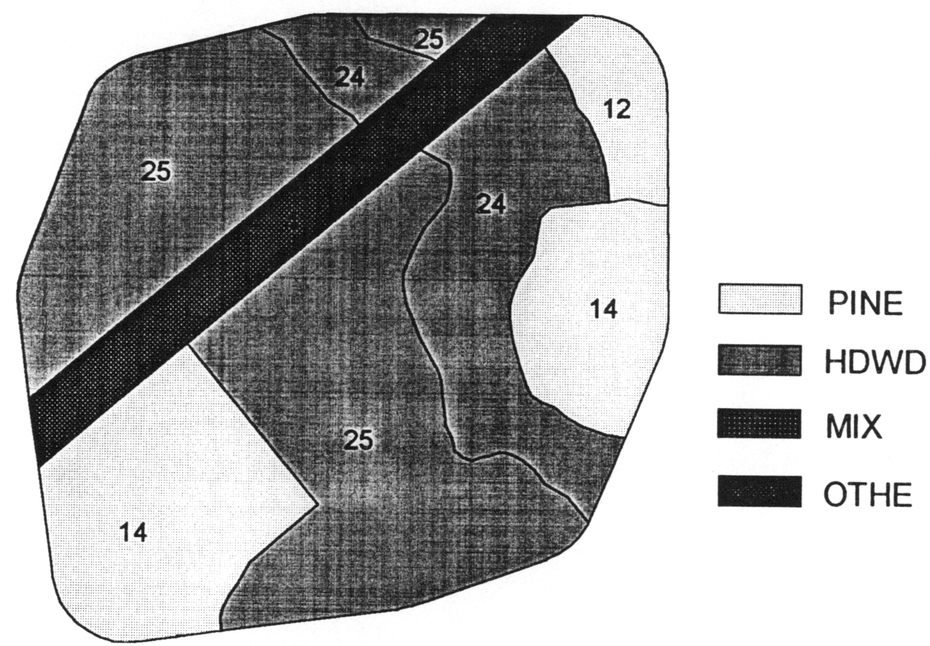
Generalized Habitat Type

Appendix M. Continued.

Site 10

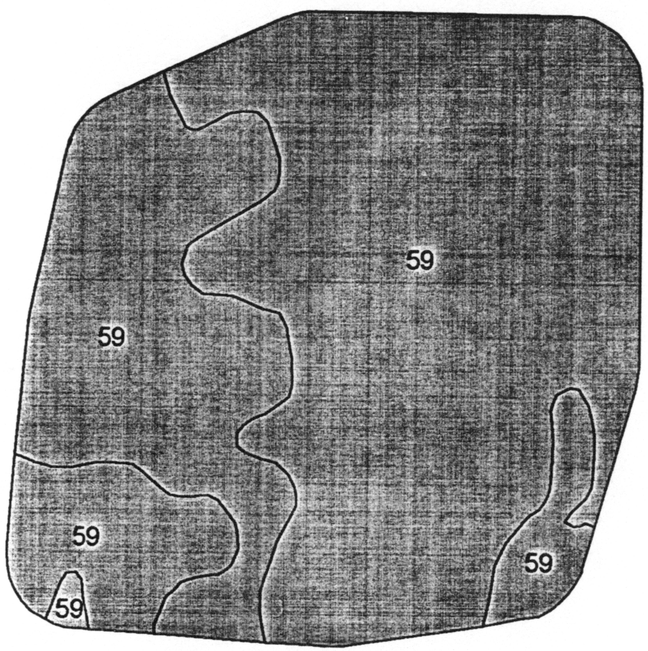


SAF Cover Type

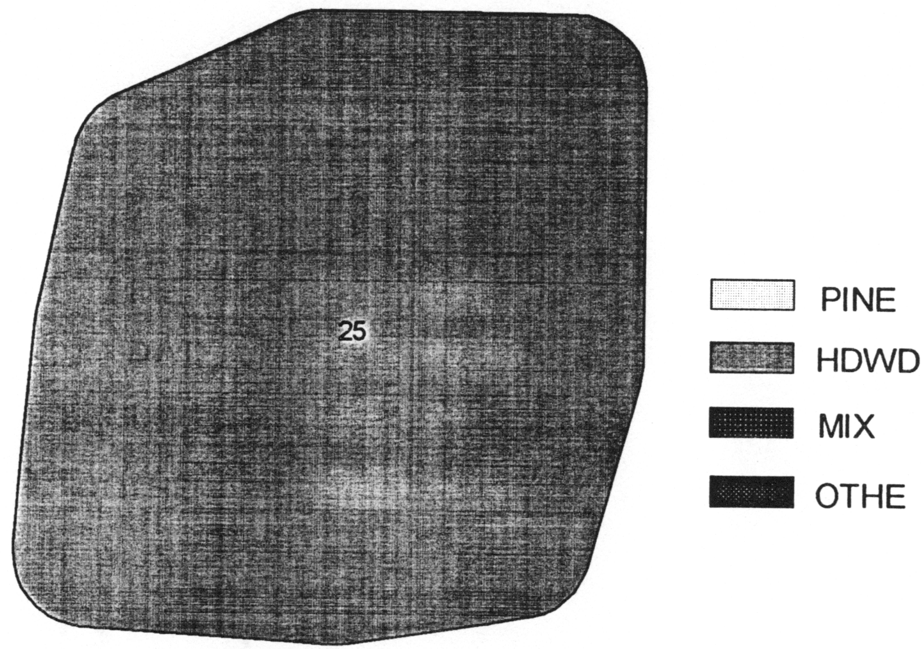


Generalized Habitat Type

Site 11

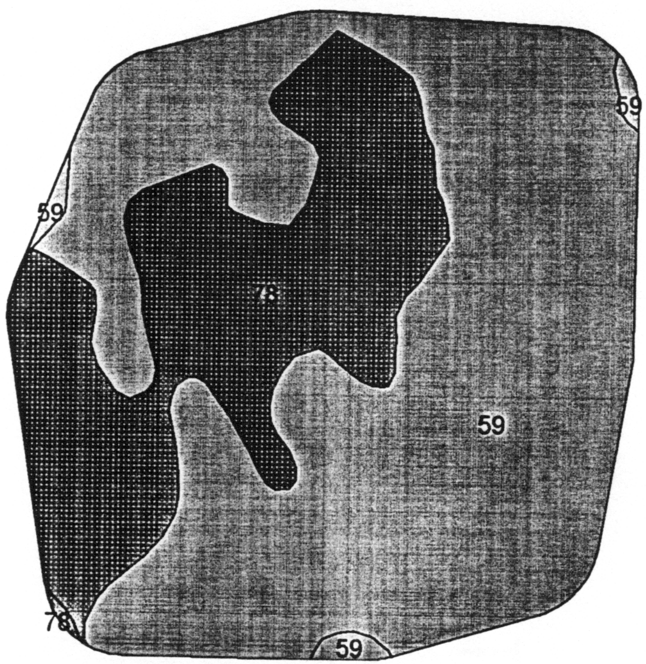


SAF Cover Type

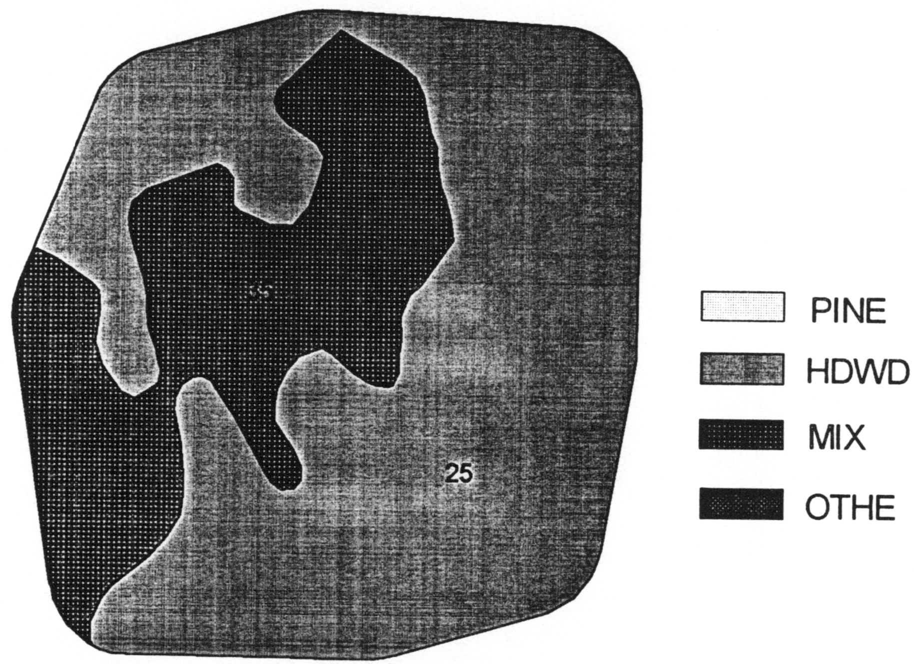


Generalized Habitat Type

Site 12



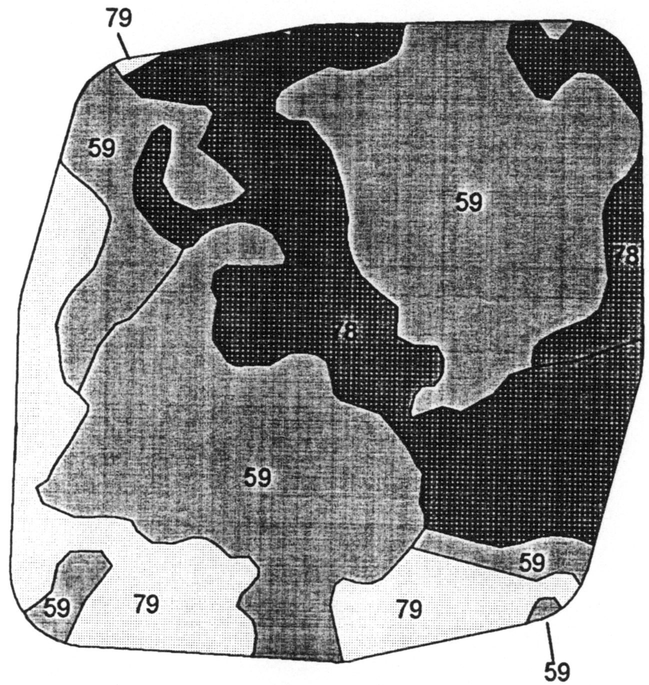
SAF Cover Type



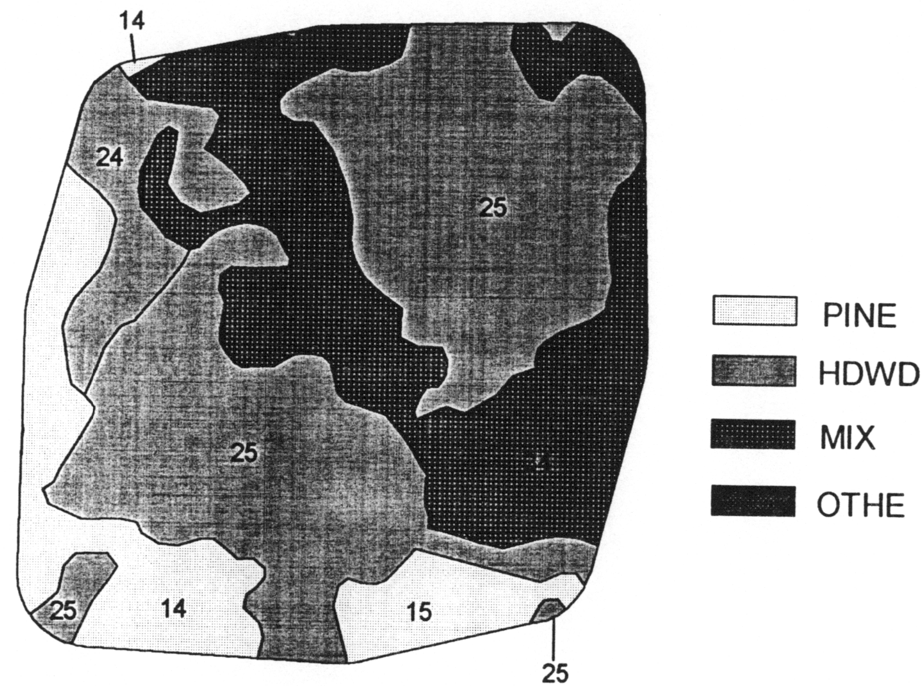
Generalized Habitat Type

Appendix M. Continued.

Site 13

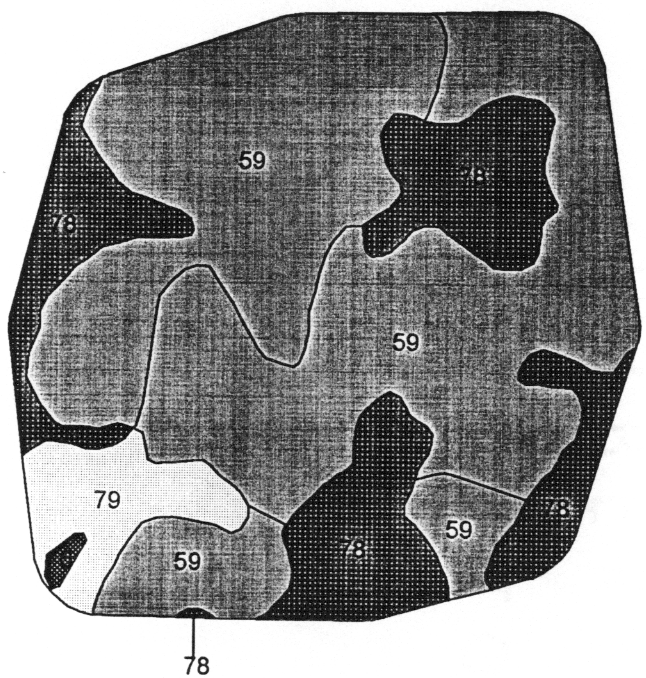


SAF Cover Type

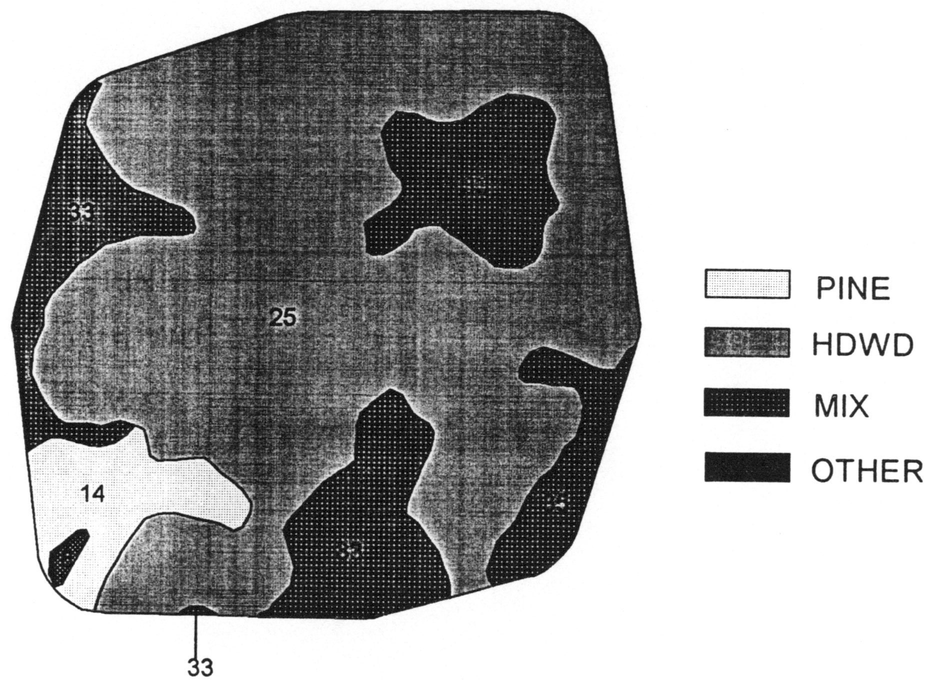


Generalized Habitat Type

Site 14

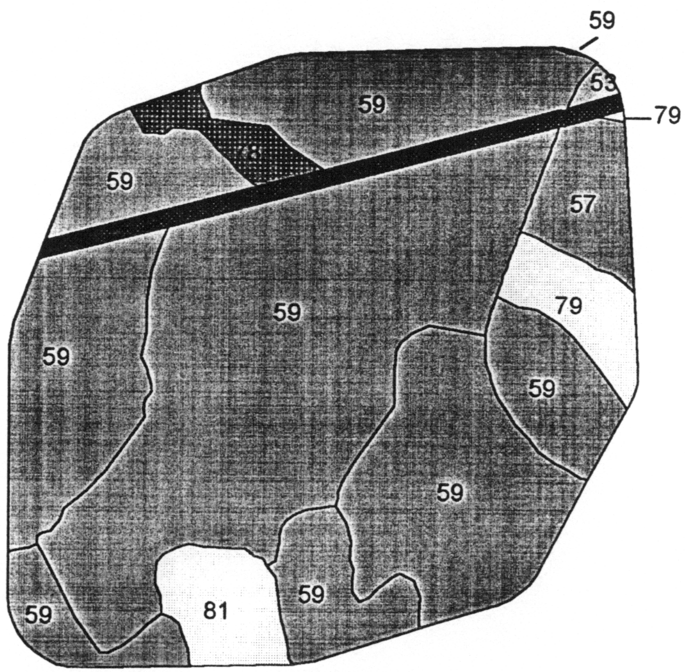


SAF Cover Type

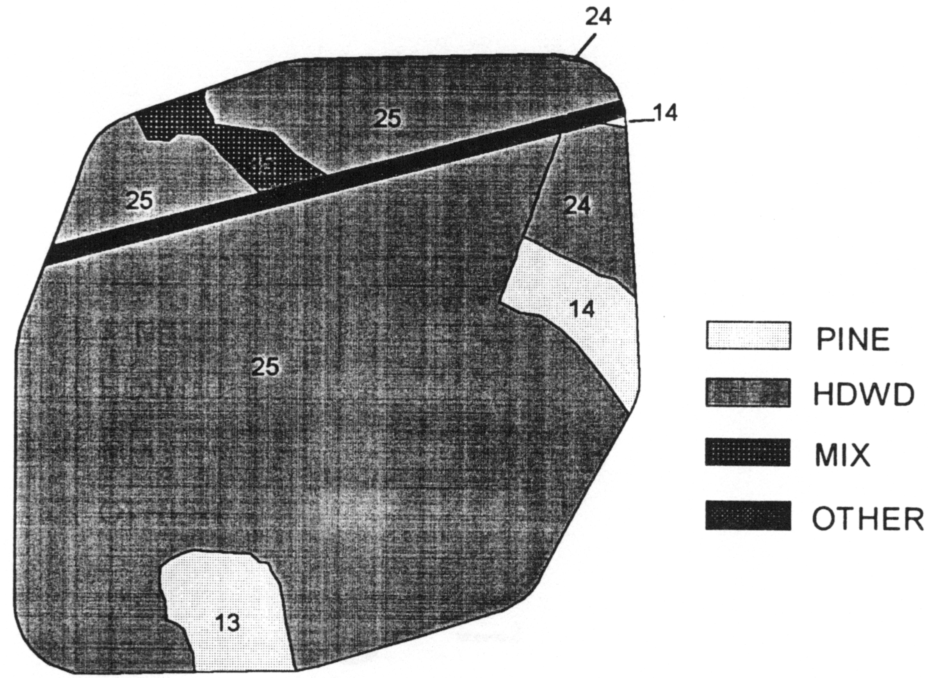


Generalized Habitat Type

Site 15

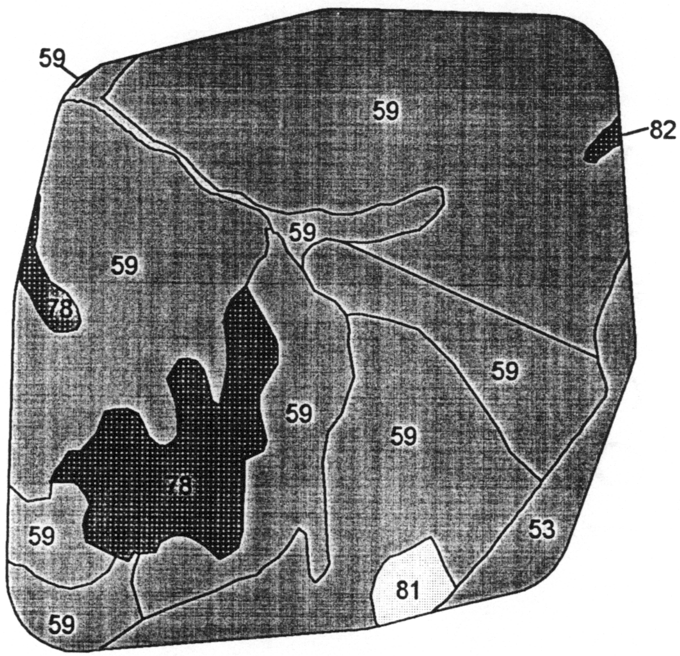


SAF Cover Type

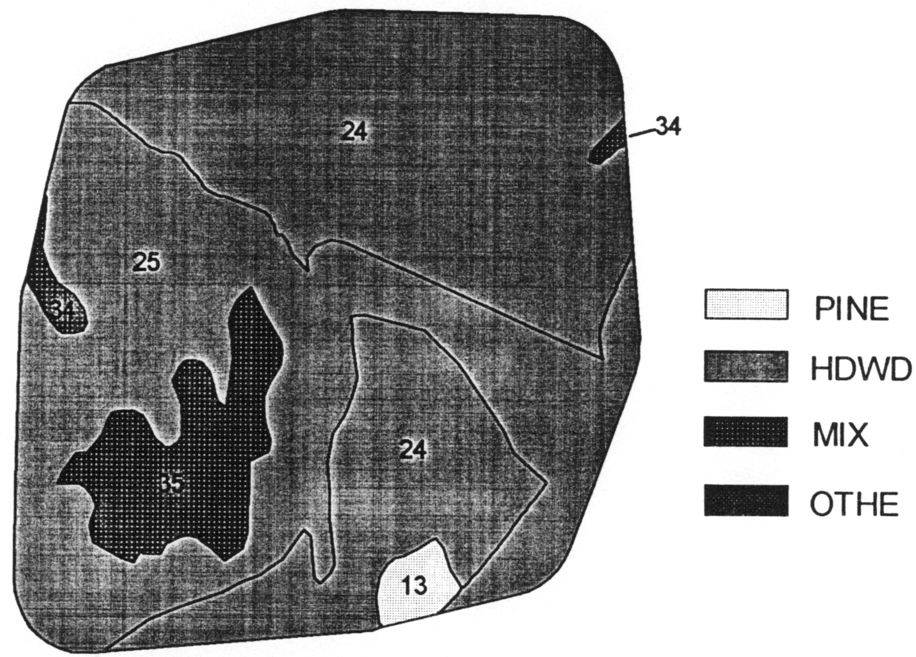


Generalized Habitat Type

Site 16

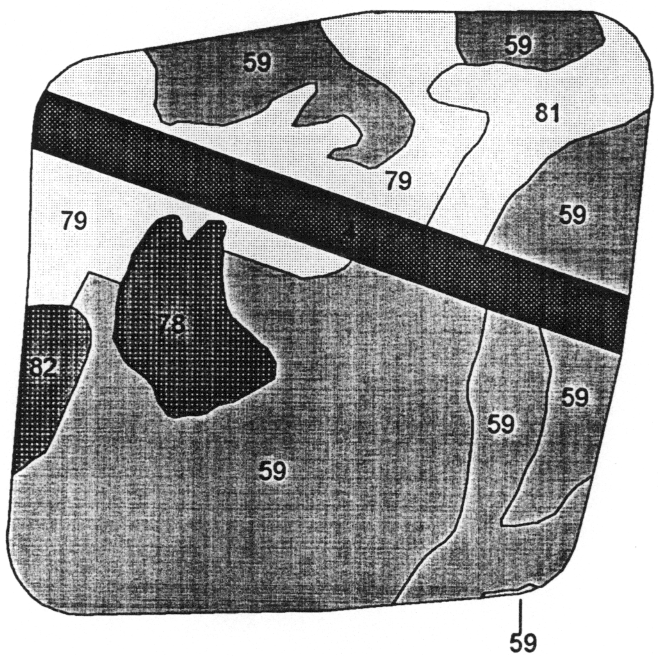


SAF Cover Type

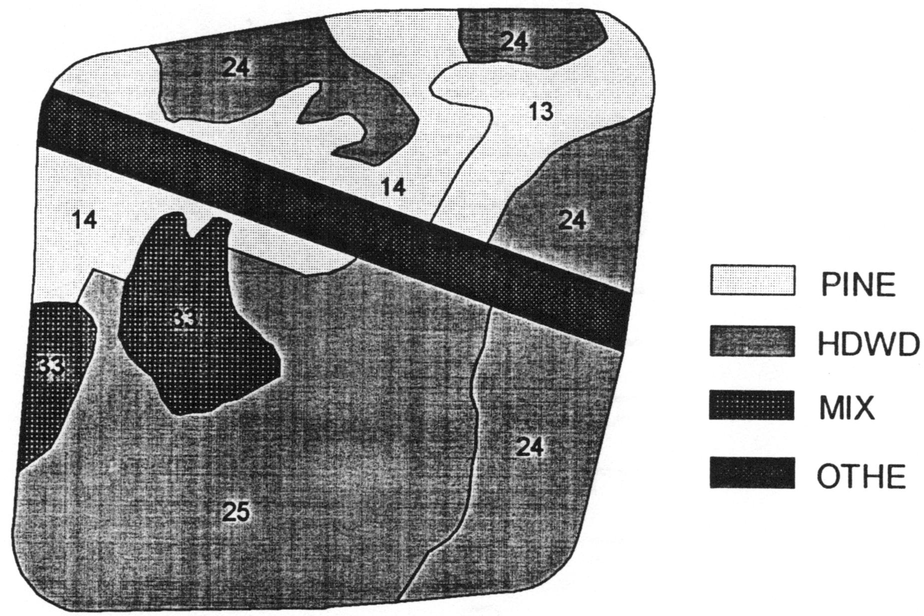


Generalized Habitat Type

Site 18

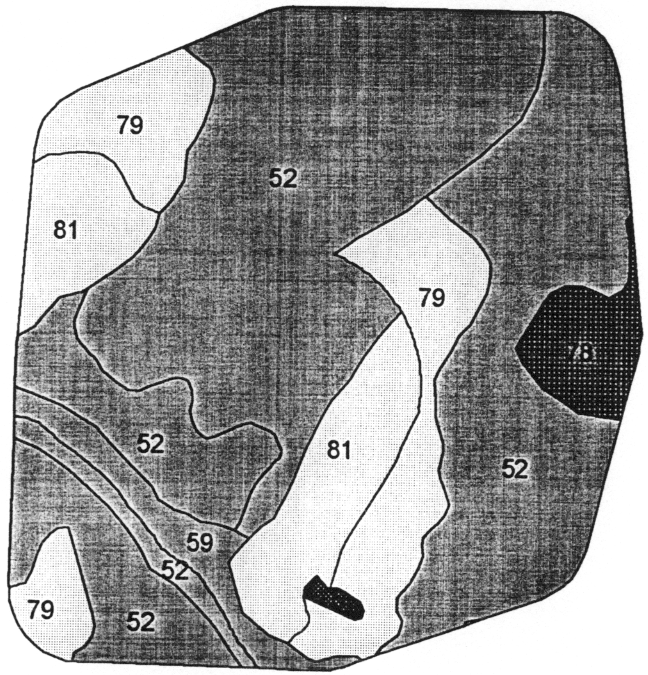


SAF Cover Type

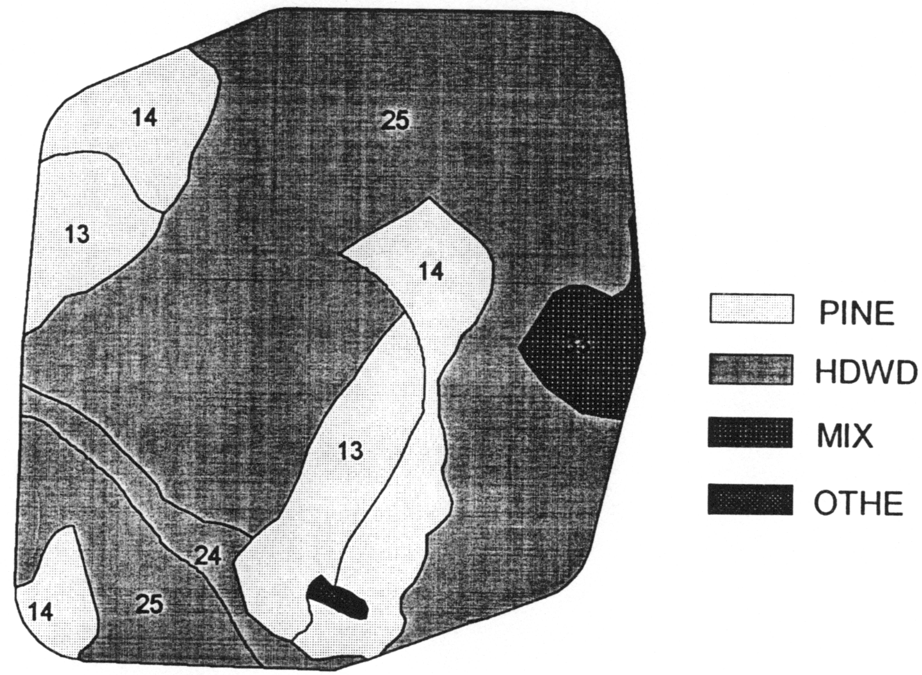


Generalized Habitat Type

Site 19

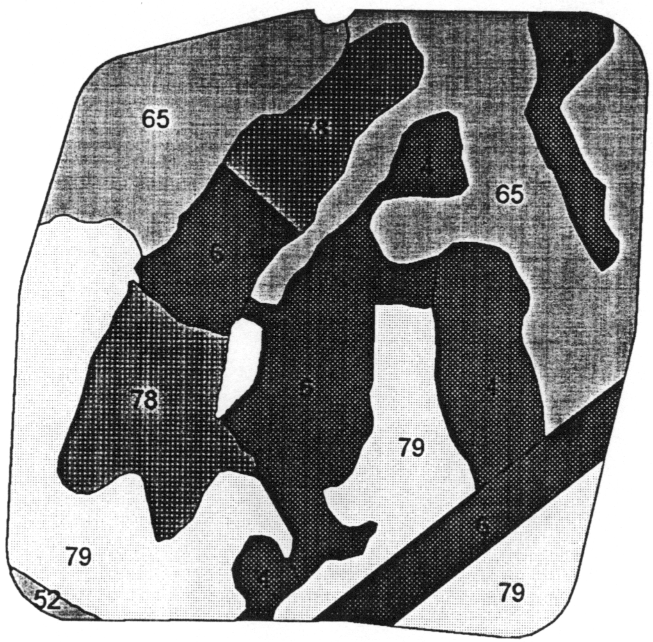


SAF Cover Type

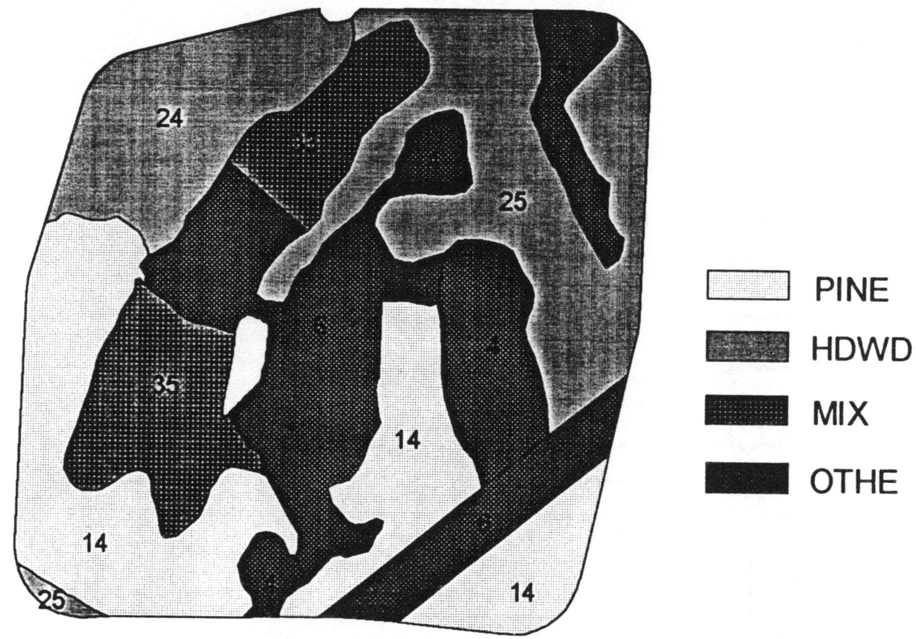


Generalized Habitat Type

Site 20



SAF Cover Type



Generalized Habitat Type

[a] Site 17 was not able to be reproduced due to difficulties in exporting its GIS coverage from the UNIX to the PC environment.
[b] See Table 2. for definitions of patch codes.

Vita

Mark E. Penhollow was born in Buffalo, NY on April 3, 1970. After graduating from Clarence Senior High School in 1988, he attended the State University of New York College at Oswego where he studied for 2 years before transferring to the State University of New York College of Environmental Science and Forestry (SUNY ESF). In May of 1992, he graduated with high honors (*magna cum laude*) from SUNY ESF with a Bachelor of Science degree in Environmental and Forest Biology. Shortly after graduating, he was employed by Colorado State University as a wildlife technician. He was involved with the University's Land Condition Trend Analysis (LCTA) program being conducted on the Fort Drum Military Installation in Fort Drum, NY. In March of 1993, he accepted a Wildlife Biologist position with the USDA Forest Service's Pacific Southwest Research Station. He was involved in 2 studies, a demographic study of the California spotted owl (*Strix occidentalis occidentalis*) in the Sierra National Forest, CA and a winter-habitat use study of black-tailed deer (*Odocoileus hemionus columbianus*) in the Shasta-Trinity National Forest, CA. In the spring of 1994, he was awarded a Graduate Research Assistantship at Virginia Polytechnic Institute and State University, where he pursued a Master of Science degree in Wildlife Sciences. He received his Master of Science degree in November of 1996.

Mark E. Penhollow