

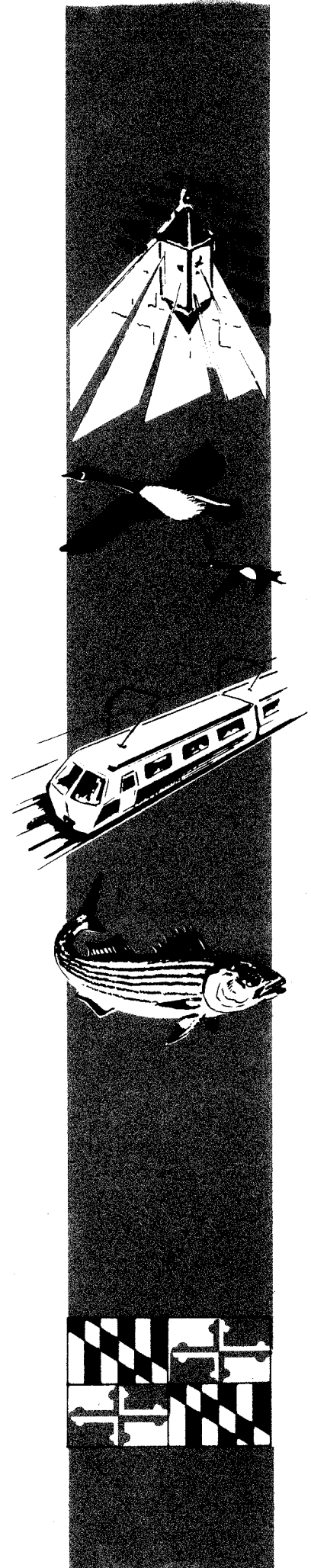
CONFIGURATION OF FOREST PATCHES NECESSARY TO MAINTAIN BIRD AND PLANT COMMUNITIES

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CONTENTS

	<u>Page</u>
EXECUTIVE SUMMARY	1
INTRODUCTION	3
METHODS	
I. Study Area	5
II. Selection of Forest Patches	5
III. Point Surveys of Breeding Birds	7
IV. Vegetation Surveys	9
V. Data Analysis	10
VI. Statistical Methods	13
RESULTS	
I. Distribution and General Characteristics of Forest Patches	14
II. Birds	
A. Community properties	15
B. Responses of individual species	18
III. Vegetation	
A. Community-level responses	21
B. Species-level responses	23
DISCUSSION	
I. Bird Populations: Importance of Forest Area vs Other Factors	25
II. Habitat Disruption vs Migratory Strategy	30
III. Implications for Conservation and Management	32
IV. Effects of Habitat Fragmentation on Plants	38
ACKNOWLEDGMENTS	40
LITERATURE CITED	41

CONTENTS (continued)

	<u>Page</u>
TABLES	45
FIGURES	57
APPENDICES	63

EXECUTIVE SUMMARY

The abundance and diversity of forest birds and plants were studied in relation to the size, degree of isolation, floristics, physiognomy, and successional maturity of upland forest patches in the coastal plain province of Maryland. Point surveys were used to obtain a quantitative index of bird abundance and diversity. Structural and floristic characteristics of the tree, shrub, and herb layers were measured at each site.

Results of this study indicate that the local breeding abundance of almost every bird species associated with the interior of upland forests is significantly influenced by forest area, isolation, structure, or floristics, or combinations of these factors. Highly migratory species tend to be most abundant in extensive stands of diverse, mature forests that are only slightly isolated from sources of potential colonists. Permanent residents and short-distance migrants are less responsive to variation in these site characteristics, or show responses that are opposite those shown by long-distance migrants. Relatively few plant species respond to site characteristics that influence birds. However, several structural and floristic properties of forest vegetation, as well as the abundances of a few individual herb, shrub, and tree species, do show statistically significant associations with one or more site factors.

The responses of birds to forest fragmentation are complex and species-specific. Many species strongly respond to factors other than, or in addition to, forest patch area and isolation. The small magnitudes of most regression coefficients involving isolation indicate that minimal impact on bird populations would be expected in situations where large forest tracts are separated by distances of a few tens of meters. Dissection of the landscape into small highly isolated patches of forest will adversely affect many bird species, but structural

and floristic characteristics of the forest are at least as important as patch size and isolation. These habitat "quality" factors should be considered when management decisions are made for bird preservation.

INTRODUCTION

Except for riparian corridors and a dwindling number of large secondary successional wooded tracts, formerly extensive upland forests on the central Atlantic coastal plain have been converted to an archipelago of relatively small "islands" and peninsulas of habitat that are bordered by agricultural land, pastures, fallow fields, roads, or settled areas. The process of insularization has accelerated in recent decades in the heavily populated coastal corridor, a fact which may have severe implications for the preservation of biotic diversity in this region (Forman et al., 1976; Lynch and Whitcomb, 1978; Robbins, 1980; Whitcomb et al., 1981). The objectives of the present research were to quantify some of the effects of habitat fragmentation on birds and plants that inhabit tracts of upland forest in the coastal plain of Maryland. The general questions addressed were as follows:

1. How do forest-inhabiting bird species differ in their responses to habitat fragmentation that is frequently associated with construction of power lines, roads, farms, housing developments, and other modes of human disturbance?
2. Are plant species similar to birds in their responses to habitat fragmentation?
3. Do early and middle successional woodlots provide suitable breeding habitat for most forest-interior bird species?
4. Are there specific management practices that might ameliorate the effects of habitat fragmentation? Possible strategies would include linkage of isolated forest patches with wooded corridors or "stepping stones" of habitat to promote inter-patch movement, localization of human disturbance at minimally disruptive locations (e.g., peripheral rather than central portions) of forested tracts, and manipulation of forest structure or floristics.

In addition to their intrinsic ecological interest, these questions are relevant to planners contemplating construction of roads and powerline rights of way. Information on the likely effects of construction activities on the integrity of natural plant and animal communities should be incorporated into such planning.

METHODS

I. Study Area

The study area comprised six counties (Anne Arundel, Prince Georges, Charles, Kent, Queen Annes and Talbot) in the coastal plain province of Maryland (Fig. 1). The first three counties are on the "Western Shore" of Chesapeake Bay; the other three are "Eastern Shore" counties. In general, the intensity of human disturbance decreases from north to south in the Western Shore counties, such that Anne Arundel and Prince Georges counties have less remaining forest than does Charles County (Brush et al., 1980). A north-south gradient in disturbance is not evident on the Eastern Shore. The latter area is more intensively farmed, and remaining woodlots tend to be separated by extensive areas of cropland.

II. Selection of Forest Patches

The overall aim of the study was to quantify patterns of occurrence of birds and plants in isolated tracts of upland forest. Patches were first selected by examining USGS topographic maps. Measurements of patch area and isolation were made from recent aerial photographs provided by the USDA. Criteria for selection of forested tracts for the study were as follows:

1. Area — We sought to include forest patches representing a broad range of areas. Tracts less than 5 ha were not included in the main study, because the point surveys used to estimate bird densities may be "contaminated" by species from surrounding open habitats in very small tracts. We did, however, perform a limited number of bird surveys in 2 - 4 ha patches to determine the lower area limit for occurrence of particular bird species. We set no upper limit to the area of the tracts surveyed and some exceeded 1000 ha of essentially continuous forest.

2. Isolation — As with area, we attempted to include a wide range of variation in the isolation of forest patches. Conceptual problems arose in regard to both the definition and the measurement of isolation. For purposes of this study, we considered a tract to be isolated if it was separated from other forests on all sides by at least 10m of open land. Thus, a large forested area that was bisected by a road would be considered to constitute two isolated tracts, although the degree of isolation would be quite small in this example. Other workers might choose to consider some other distance (say, 100 m) as the critical cutoff between isolated and non-isolated forest patches. However, any such criterion is arbitrary, and it is difficult to imagine that 0 or 10 m cutoff could have seriously biased the apparent response of bird species to increasing isolation.

We computed three measures of isolation, each of which was intended to assess a different aspect of patch separation. Isolation measure ISA was the shortest distance between the edge of a given forest tract and the nearest forested area of at least 100 ha. This was thought to be an appropriate metric for isolation in bird species that are unlikely to breed in small patches of forests. Isolation measure ISB was the shortest distance to the nearest forest of at least 50 ha. This measure might be relevant if tracts smaller than 100 ha are used as breeding sites, population reservoirs, or "stepping stones" that functionally connect larger forest patches. A third measure of isolation (ISC) was the median distance from the edge of a forest patch to the nearest tract of at least 50 ha, based on 8 distances measured in the 8 principal compass directions. ISC might be a relevant metric if it is the overall regional configuration of forest tracts, rather than any single interpatch distance, that influences local population density.

Although our three isolation indices were developed primarily for analysis of bird occurrences, they may also be relevant to plants. Virtually every forest patch showed evidence of some degree of past disturbance, and it is likely that these and other upland forests in eastern Maryland have been subjected to different past land uses (Brush et al., 1980; D. Higman, personal communication). Forests that have not been completely cleared at some time in the past have nevertheless been subjected to grazing or selective logging. Thus, existing forest vegetation in this region represents the cumulative effects of many forms of human intervention, and recolonization by plant species from nearby and/or distant sources of propagules could be an important component in the floristic development of a given forest patch.

3. Other Criteria -- Because we wished to restrict our analysis to upland (i.e., non-riparian) forest tracts, we attempted to avoid tracts that contained continuously flowing streams. For patches smaller than about 50 ha this restriction presented no particular problem, but many of the larger patches did contain small, usually ephemeral, streams. In such instances care was taken to conduct bird and plant surveys as far as possible from the stream areas.

Patches with extreme length:width ratios ($l:w > 3.0$) were not included so as to minimize possible perimeter effects. Our only other conscious bias in the selection of patches for inclusion in the study was avoidance of tracts that were undergoing, or recently had undergone, severe disturbance from logging, grazing, fire, or other human-related activities.

III. Point Surveys of Breeding Birds

The single point survey method (MacClintock et al., 1977; Lynch and

Whitcomb, 1978; Robbins, 1979; Whitcomb et al., 1981) was used to obtain an index of the occurrence and relative abundance of breeding bird species. This technique is a slightly modified version of the I.P.A. (Indice Ponctuel d'Abondance) developed earlier by European workers (Blondel et al., 1970; Ferry, 1974).

Results of the single point survey method have been compared with data obtained from much more labor-intensive breeding bird spot-mapping by Whitcomb et al. (1981) who concluded that three 20-minute point surveys are sufficient to discover about 90% of the species present in an area. The two techniques yield comparable estimates of relative abundance of the commoner species.

On each visit the position and identities of singing territorial males, calling individuals, and birds seen but not heard were recorded on a map. Based on observer familiarity with the local breeding avifauna, a decision was made as regards the breeding status of non-singing birds encountered during the survey. Relative local densities were determined from records of simultaneously singing territorial males, and from the presence of a species on 1, 2, or 3 of the survey dates. The seasonal total number of breeding pairs per point was estimated as the maximum number of territorial males perceived on any one visit. While the maximum distance of detectability, and hence the absolute estimate of density, will vary from species to species, quantitative comparisons of a given species can be made among plots (Whitcomb et al., 1981). For tracts up to about 100 ha in extent, the center of the tract was chosen as the survey point; in larger tracts the survey point was not always at the geometric center, but was far enough from the margins (at least 100m) to be representative of forest-interior conditions. In order to increase the completeness of our coverage within large forest tracts, two survey points were chosen in patches of 50 -100 ha, and three points were chosen for patches larger than 100 ha. A practiced observer could perform as many as five

20 minute point surveys during a morning period of observation, depending on the logistical difficulties in getting from one survey point to the next. These difficulties were reduced by marking a trail to the survey point in advance of the survey date. All surveys were conducted during early to mid-morning (0530 - 1000) and each point was surveyed three times during the breeding season.

All birds encountered were noted, but we restricted our analysis to the smaller (body weight < 50 g) diurnal species that breed in upland forest habitat. "Edge" species (e.g., common crow, mourning dove) were excluded, as were hawks, owls, and caprimulgids.

IV. Vegetation Surveys

Vegetation was sampled in 196 forest patches on the Western Shore in 1979 and in 74 patches on the Eastern Shore in 1980. Sampling procedures were based on the techniques developed by James and Shugart (1970). Five circular 0.04 ha plots were sampled in all patches that were less than 100 ha in size. Ten such plots were sampled in forests larger than 100 ha. The approximate center of each forest patch was located on U.S.G.S. topographic maps. This central point was used for both the plant and bird surveys. One 0.04 ha plant sampling plot was placed at the central point, and the locations of the remaining 4 vegetation plots were chosen by random selection of directions and distances from the central point. Stem diameters of all trees greater than 10 cm dbh were measured within each plot. Shrubs (i.e., all woody plants less than 10 cm dbh) were counted in two 2m x 22m transects that intersected at the center of each plot. Four 1 m² herb plots were randomly positioned within each 0.04 ha plot. Abundance and cover estimates were made for all herbaceous plants within each 1 m² plot. We used abundance and cover values (Appendix A) that were adapted from Shimwell (1971).

Many plants were not flowering at the time they were sampled, or were otherwise difficult to identify in the field. Pressed samples of each unidentified plant were collected, and voucher specimens were identified by reference to the collection at the U.S. National Herbarium. Especially difficult groups (e.g., Cyperaceae, Poaceae, Fabaceae) and vegetative materials from other taxa were sent to experts for identification. Our nomenclature follows Radford et al. (1964) and/or Gleason and Cronquist (1963).

Mean canopy height for each patch was determined at the central sampling plot by averaging 5 canopy height measurements made with a Haga altimeter. Percent canopy cover was visually estimated at the same location.

The following summary data were calculated for each species in each forest patch (Equations used in the calculations are in Appendix B).

TREES: Density, relative density, frequency, relative frequency, basal area, relative basal area, relative dominance.

SHRUBS: Density, relative density, frequency, relative frequency, relative dominance.

HERBS: Average cover class, relative cover class, average abundance class, relative abundance class, frequency, relative frequency, relative dominance.

V. Data Analysis

Our approach was to statistically screen a large set of potentially important predictor ("independent") variables in an effort to quantify their individual and combined effects on community-level and species-level response ("dependent") variables. The community-level response variables included various measures of diversity and density for birds and plants as follows:

A. Birds

1. Total number of bird species (TBS) — number of species encountered in a given tract during the three surveys.
2. Total number of pairs of birds (TBP) — minimum total number of different pairs encountered during the point surveys.
3. Bird diversity (BDE) — Calculated as the exponential form of the familiar Shannon-Weiner diversity statistic ($BDE = \ln^{-1} (-\sum p_i \ln p_i)$), where p_i = proportion of total number of birds that is contributed by individuals of species i . BDE is the effective number of equally abundant species sampled.
4. Number of forest-interior bird species (FSP) — number of surveyed species that normally breed within forest (as opposed to "edge" or open habitats). Lynch and Whitcomb (1978) and Whitcomb et al. (1981) discuss criteria for assigning species to this category, which includes the interior and interior-edge groups of Whitcomb et al. (1981).
5. Abundance of forest-interior species (FPR) — number of pairs that belong to species which normally breed within forest.
6. Number of "edge" species (ESP) — number of surveyed species that are primarily associated with "edge"-habitat, clearings, or other habitat besides forest-interior (Whitcomb et al., 1981).
7. Abundance of "edge" species (EPR) — number of pairs belonging to species that normally do not breed in undisturbed forest.

B. Plants

1. Total plant species (TPS) — combined number of species in herb, shrub, and tree layers.

2. Total tree species (TTS)
3. Total shrub species (TSS)
4. Total herbaceous species (THS)
5. Tree diversity (TDE) -- exponential form of Shannon-Weiner diversity statistic.
6. Shrub diversity (SDE) -- exponential form of Shannon-Weiner diversity statistic.
7. Herb diversity (HDE) -- exponential form of Shannon-Weiner diversity statistic.

The species-level response variables we studied were: a) the estimated densities for each of the 31 most common forest-interior bird species, and b) dominance index for each plant species.

We examined the statistical relationships between the above community-level and species-level response variables and the following predictor variables:

1. Forest area (LAR) -- the natural logarithm of the area in hectares.
2. Isolation from the nearest large forest tract (ISA) -- measured as the straight-line distance (in tenths of km) between the edge of a given tract and the nearest continuous forest of at least 100 ha.
3. Isolation from nearest medium-sized forest tract (ISB) -- measured as the straight-line distance (in tenths of km) between the border of a given tract and the nearest continuous forest of at least 50 ha.
4. Average isolation from medium-sized forest tracts (ISC) -- computed as the median distance (in tenths of km) from a given

tract to the nearest continuous forest of at least 50 ha in each of the eight principle compass directions (N, NE, E, SE, S, SW, W, NW).

5. Canopy height (CHT) — average height (in meters) of canopy trees at center of forest patch.
6. Percent canopy cover (PCC) — estimated canopy closure of forest at center of patch.
7. Pine dominance (PIN) — sum of the relative densities of Pinus virginiana and P. taeda in each forest patch.
8. Tree density (FDT) — average number of woody stems (dbh > 10 cm) per hectare.
9. Shrub density (NSD) — average number of woody stems (dbh < 10 cm) per hectare.
10. Herb density (HCT) — average percent cover of herbs in each forest.
11. Basal area of forest (BAF) — average basal area (m^2/ha) of each forest patch sampled.

VI. Statistical Methods

Stepwise linear regression (Draper and Smith, 1966) was used to generate predictive equations for community and species level responses of plants and birds to structural and floristic aspects of forest composition. The computed equations include all predictor variables that show statistically significant partial correlations with the response variable in question. Beginning with the predictor variable that is most highly correlated with the response variable in question, the stepwise method successively includes additional predictors in the order of their decreasing ability to reduce "unexplained" or residual variation in the response

variable. The stepwise addition of new predictors to the regression equation is terminated when further reduction in the residual variance is statistically non-significant (i.e., when $p > 0.05$).

RESULTS

I. Distribution and General Characteristics of Forest Patches

Bird surveys were performed in a total of 270 forest patches, but due to the time-intensive nature of the plant surveys we were able to obtain vegetation data for only 183 of those sites. The locations of the forest patches sampled are shown in Fig. 1. Although some vegetation associations mapped by Brush et al. (1980) occur on both shores of Chesapeake Bay, there are clear differences in their distribution. Thus, the Tulip Poplar and Chestnut Oak - Post Oak - Blackjack Oak associations are prevalent on the Western Shore, while the Basket Oak - Loblolly Pine and Willow Oak - Loblolly Pine associations are most common on the Eastern Shore.

Most of the 196 study sites in the 3 Western Shore counties fell within the Tulip Poplar assemblage (115 patches) or the Chestnut Oak - Basket Oak - Blackjack Oak assemblage (46 patches); the 35 remaining patches were divided among 4 assemblages with restricted distribution in the study area (Table 1). Most of the 74 forest patches on the Eastern Shore were mapped by Brush et al. (1980) as Basket Oak - Loblolly Pine (39 patches) and Willow Oak - Loblolly Pine (19 patches) associations. A few (11) of the northernmost patches on the Eastern Shore were in areas mapped as Tulip Poplar association, and 5 patches were in the Basket Oak assemblage.

The explanation for the existence of different forest types on the two sides of Chesapeake Bay is beyond the scope of the present analysis, but edaphic and

topographic factors (such as differences in soil types, and the flatter, less well-drained terrain on the Eastern Shore) presumably are responsible (Strahler 1977), for the two areas are closely similar in temperature and mean annual precipitation. Agricultural and silvicultural practices differ markedly on the two sides of the Bay: farms are much larger, and woodlots are more intensively managed on the Eastern Shore than on the Western Shore. In addition, existing land use patterns appear to be more stable on the Eastern Shore. Comparison of USGS topographic maps and aerial photographs prepared over the past 20 years reveal little change in the configuration of forest tracts in Eastern Shore counties, whereas rapid suburbanization in the past 20-30 years has destroyed or fragmented many forest patches on the Western Shore (Figs. 2 and 3).

As summarized in Table 2 and Fig. 4, average characteristics for forest patches differed somewhat on the two shores of Chesapeake Bay although large variances were associated with most variables. Relative to patches on the Eastern Shore, Western Shore woodlots tended to be larger (mean area = 31 vs 18 ha), less isolated (ISA = 0.7 vs 1.8 km), less dominated by pine (PIN = 2.3 vs 21.0 trees/ha), and richer in trees (TDE = 8.5 vs 7.6 equally abundant species), shrubs (SDE = 18 vs 14 equally abundant species), and herbs (HCT = 9 vs 5 equally abundant species). On the other hand, despite floristic differences, forest tracts on the two sides of the Bay were closely similar in some respects including tree density (FDT = 555 vs 535 trees/ha), basal area of trees (BAF = 29 vs 29 m²/ha), and mean canopy height (CHT = 24 vs 23 m).

II. Birds

A. Community properties

The community-level variables we analyzed were total species number, total number of pairs, exponential diversity of bird species, number of forest-interior

species, number of pairs of forest-interior species, number of "edge" species, and number of pairs of "edge" species. Results are summarized in Table 3.

Total bird species (TBS) — For the Western Shore the only significant correlations were negative associations with PIN and ISB. Thus, non-isolated tracts with few pines tended to have more species. The relationship was statistically highly significant ($p < .001$), but the multiple correlation coefficient was relatively low ($R = .30$).

This means that only about 9% ($= R^2$) of the variance in the total number of bird species could be attributed to variation in the predictor variables we used. For the Eastern Shore, the strongest determinant of total species number was patch area (LAR) area, but the relationship was negative: smaller tracts tended to have more bird species at a given point. Canopy height (CHT) and herb cover (HCT) also showed significant negative associations with TBS. The combined predictive power of the four independent variables was moderate ($R = .53$; $p < .001$), such that 28% of the variance in species number could be "explained" by the combined effects of the predictor variables. When results from both sides of Chesapeake Bay were combined, only patch area (LAR) remained a statistically significant predictor of TBS, and the relationship was a relatively weak negative one ($r = \text{simple correlation coefficient} = -.22$; $p < .01$).

Total number of pairs of birds (TPB) — For the Western Shore sites, the significant partial correlations with TPB were negative associations with isolation (ISA) and shrub density (NSD), and a positive association with herb density (HCT), ($R = .42$; $p < .001$). For the Eastern Shore counties, forest area showed a significant negative correlation with TPB ($r = -.32$; $p < .01$). For the two shores combined, HCT, ISB, BAF, and LAR all contributed significantly to the prediction of TPB ($R = .35$; $p < .001$).

Bird diversity (BDE) — The exponential species diversity index was weakly related to tree density (FDT) on the Western Shore. ($r = .26$; $p < .01$), and was not significantly correlated with any predictors on the Eastern Shore ($p > .05$ for all predictor variables). For both shores combined, FDT was a weak but statistically significant predictor ($r = .19$; $p < .05$).

Number of forest-interior bird species (FSP) and individuals (FPR) — Because a majority of birds encountered in the point surveys were forest-interior species, one would expect that predictor variables associated with total species number and total number of pairs of birds also should be correlated with the number of pairs and species of forest-interior birds (FPR and FSP). In fact, this proved to be true for only some of the important predictor variables.

On the Western Shore herb diversity (positive) and ISA (negative) were the best predictors of FSP ($R = .40$; $p < .001$), whereas FPR was significantly influenced by HCT, ISA (negative) and BAF ($R = .53$; $p < .001$). For the Eastern Shore, there were no significant correlations between FSP and any of the predictor variables, but FPR showed a significant negative correlation with ISB ($r = -.22$; $p < .05$). Pooled data for both shores showed a weak but statistically significant relationship between FSP and HDE ($r = .23$; $p < .01$), and a stronger relationship between FPR and TPS, BAF, ISA, and HCT ($R = .56$; $p < .0001$).

Number of "edge" species (ESP) and individuals (EPR) — This group of birds was expected to respond to disturbance differently from forest-interior species, and this was indeed the case. For both the Western and Eastern Shores, the best predictor of number of species and pairs of "edge" birds was LAR, but the sign of the correlation is negative; thus, small patches have more "edge" species and individuals. For the Western Shore, CHT also showed a significant negative correlation with ESP ($R = .37$; $p < .01$), while on the Eastern Shore these two

variables plus HCT were significantly correlated with ESP ($R = .66$; $p < .001$). EPR showed significant negative correlations with LAR, PCC, and BAF on the Western Shore ($R = .46$; $p < .001$). On the Eastern Shore, the significant correlations of EPR were with LAR, TPS, and CHT ($R = .69$; $p < .001$).

B. Birds: Responses of Individual Species

In this discussion, only the combined occurrence of species on both shores will be considered. Complete data for Eastern and Western Shores are given in Appendix F. The local abundances of 30 of the 31 most common forest-interior species proved to be significantly correlated with one or more of the 15 predictor variables utilized in the regression analysis (Table 4). The sole exception was Pileated Woodpecker, which occurred in only 17 of the 180 forest patches for which complete data are available. The relative rarity of this species, combined with its very large territorial size, made it difficult to pinpoint factors that control the occurrence of Pileated Woodpecker from surveys of small plots.

The association of local abundance levels of individual bird species with the 15 predictor variables can be conveniently summarized by combining the predictors into the following functional groups: patch area (1 vbl), patch isolation (3 vbls), physiognomy of tree stratum (4 vbl), physiognomy of herbaceous and shrub understory (2 vbls), abundance of conifers in forest (1 vbl), floristic diversity (4 vbls).

Patch Area (LAR) — Local density of 8 bird species showed a statistically significant dependence on patch size, measured as the natural logarithm of patch area (Tables 4 - 6). Five species, all of them neotropical migrants, were significantly more abundant in larger tracts; three species, (a neotropical migrant, a short-distance migrant, and a permanent resident) were more common in smaller tracts. The data support the hypothesis that neotropical migrants tend to be more

sensitive than either resident species or short-distance migrants to reduction in forest size.

Patch Isolation (ISA, ISB, ISC) — More than half (16 of 31) of the bird species exhibited statistically significant correlations between their local density and one or more of the three measures of patch isolation (Tables 4 - 6). Eleven species responded to ISC (median distance to a forest of at least 50 ha), four responded to ISB (minimum distance to a forest of at least 50 ha), and three responded to ISA (minimum distance to forests of at least 100 ha). Thus, there is no basis for considering any one of the three isolation measures to be generally superior. Neotropical migrants tended to be less abundant in isolated tracts (9 of 12 significant correlations negative), but no such tendency existed for residents and short-distance migrants (4 positive, 3 negative correlations).

Physiognomy of Tree Stratum (BAF, CHT, FDT, PCC) — Eighteen species showed significant relationships between their local density and one of the descriptors of forest stature and conformation (Tables 4 - 6). Basal area of the forest (BAF), canopy height (CHT), and density of trees (FDT) each influenced 5 species, and percent canopy cover (PCC) influenced 3 species. Four of the 5 species influenced by BAF were neotropical migrants, but there is no indication of differences among the migratory groups with respect to the other three variables. In general, tall forests with incomplete canopy closure were favorable to the greatest number of species.

Physiognomy of Understory (HCT, NSD) — Local densities of 8 bird species were significantly correlated with herb cover (HCT) or shrub density (NSD), or both. Bird species, especially neotropical migrants, tended to favor forests with a high density of herbaceous ground cover (4 of 5 significant correlations positive).

Abundance of Pines (PIN) — Two Pinus species, P. virginiana and P. taeda, accounted for more than 95% of the coniferous trees encountered in the study. These pines were considered apart from the other forest trees because they provide highly distinctive foraging substrates and nesting sites, and because they are generally indicative of early or mid-successional forests in our study area. Seven bird species showed significant relationships with the prevalence of pines in the study plots, but there was no marked tendency for either positive or negative correlations to prevail (4 correlations positive, 3 negative).

Floristic Diversity (TPS, TDE, SDE, HDE) — The abundances of 16 forest-interior birds were significantly correlated with one or more plant diversity factors (Tables 4 - 6). Shrub diversity (SDE) accounted for eight significant correlations (5 positive, 3 negative), with total number of plant species (TPS) next in importance (7 significant correlations; 4 positive, 3 negative). The abundance of one species was negatively correlated with tree diversity (TDE), and no species abundance was correlated with herb diversity (HDE).

As a group, neotropical migrants strongly favored diverse plant associations - 8 of 10 significant correlations with diversity factors were positive. Residents and partial migrants showed an opposite trend - only 1 of 5 significant correlations was positive.

Summary — Measures of patch isolation, plant diversity, and tree physiognomy were the best predictors of the local abundance of birds, accounting for a grand total of 51 separate significant correlations among the 31 bird species studied. Only the Pileated Woodpecker and the Northern Cardinal had abundances that were unaffected by one of these three functional groups of predictors. As noted earlier, the Pileated Woodpecker was too rarely encountered for a meaningful analysis of its habitat requirements. In contrast, the Cardinal as also

noted by Anderson and Shugart (1974), is a very common bird, but its abundance is strongly influenced by the physiognomy of the understory (NSD, HCT), rather than that of the tree stratum (Table 4 and Appendix F).

Forest area (LAR) had a statistically significant independent effect on the local density of only 8 bird species, and was the most important predictor variable for just 3 species; an equal or greater number of species were influenced by ISC and SDE. Together, the three isolation measures accounted for 18 significant correlations.

III. Vegetation

A. Community-level responses

Isolation (ISA, ISB, ISC) — Significant community-level responses to isolation are shown in Table 7. The measure of isolation that represents the median distance between patches (ISC) was most important on the Eastern Shore, where it accounted for all of the significant responses of measures of species richness (TPS, TTS, TSS, TDE, SDE). All five correlations had a negative sign. Of the physiognomic response variables (BAF, FDT, HCT, NSD, PCC), only basal area of the forest (BAF) was significantly related to ISC (positive correlation).

Significant responses to the other two isolation measures (ISB and ISA) occurred only on the Western Shore. All but one of the four significant responses by species richness variables were negative. Among the four structural variables with significant responses to short-distance isolation one (HCT) was positively correlated and three (FDT, HCT, PCC) were negatively correlated (Table 7).

Area (LAR) — None of the species richness measures was significantly related to area, and among the physiognomic variables, only shrub density (NSD) and percent canopy cover (PCC) were related to area (Table 7). In both cases, the correlations with area were negative.

Canopy height (CHT) — All of the physiognomic community-level variables (FDT, NSD, HCT, and PCC) were related to canopy height (Table 7). Canopy height was positively correlated with BAF, and negatively correlated with tree density (FDT) on both shores. On the Western Shore, CHT was negatively correlated with shrub density (NSD), positively correlated with percent herb cover (HCT), and both the number (THS) and diversity (HDE) of herbaceous species. The increase in herbaceous species is responsible for the significant increase in the total number of plant species. The fact that fewer variables were correlated with canopy height on the Eastern Shore is most likely due to the increased density of pines in the latter region (Table 2). In general, forests with high densities of pines are intensively managed for timber production, as a result of which the understory and overstory are maintained in a state of lower overall diversity.

Abundance of Pines (PIN) — Eight community-level variables were significantly related to pine density (Table 7). The major responses to high pine density were a lower total number of plant species (TPS), lower number and diversity of tree species (TTS, TDE), lower number and diversity of herbs (THS, HDE), and a decrease in the diversity of shrubs (SDE). Eastern Shore forests with abundant pines were characterized by a higher density of trees (FDT), greater basal area (BAF), lower percent canopy cover (PCC), and lower average cover of herbaceous plants (HCT). Few Western Shore patches were dominated by pines, and the only significant relationships with PIN in that area were negative correlations with THS and HCT.

In summary, forest area was not an important predictor of community-level vegetation variables. Isolation factors were more important, and most significant correlations with isolation were negative, i.e., isolated forests tended to support less diverse plant communities. Isolation was a more important predictor of

community richness on the Eastern Shore, where woodlots show a higher mean isolation (Table 2). Canopy height and pine density showed few significant correlations with measures of species richness, although the degree of dominance of pines on the Eastern Shore seemed to be associated with a lower species diversity in the understory. In the predominantly hardwood forests of the Western Shore total plant species richness measures were significantly affected by canopy height, mainly due to an increase in species diversity in the herb layer.

B. Species - level responses

On the Western Shore, 23% of the 48 tree species, 38% of the 34 shrub species, and 7% of the 157 herbaceous species showed a significant response to at least one of the independent variables considered in the multiple regression analysis (Table 8). Thus, 15% (35/239) of the total Western Shore plant species were significantly correlated with one or more predictors. The results were similar for the Eastern Shore, where 17% of 168 plant species showed significant responses, as follows: 23% of the 35 tree species, 21% of the 61 shrub species, and 21% of the 72 herb species. Most of the tree species that showed significant correlations (72% on the Western Shore and 83% on the Eastern Shore) responded to only one predictor variable (Fig. 5). A majority of the shrub and herb species abundances that showed any significant correlations also responded to only a single predictor variable, but a sizeable minority of shrubs (39%) and herbs (36%) on the Western Shore also were significantly correlated with a second variable (Fig. 5). Very few plant species responded to any given independent variable, and there were no consistent differences in the pattern of response by species on the Eastern and Western shores (Fig. 6). Isolation and area accounted for only a small number of significant species-level responses. Forest area was not significantly correlated with the relative importance values of any herbaceous species, but was significantly

associated with the abundance of about 5% of the tree and shrub species. This number of significant responses could be explained by chance.

Isolation (ISA, ISB, ISC) — The great majority of tree species (43/48 = 90%) were not significantly correlated with patch isolation (Table 8). One species (Quercus alba) showed a negative correlation; four other species were positively correlated.

For shrubs, all significant correlations ($n = 12$) with isolation were positive on the Eastern Shore, but on the Western Shore there was no consistent pattern (4 positive, 3 negative correlations). The abundances of only two shrub species were correlated with isolation on both shores of the Bay: Pyrus americana was positively correlated with ISC on both shores, but Vaccinium atrococcum exhibited positive correlations with ISA and ISC on the Eastern Shore and a negative correlation with ISA on the Western Shore.

Abundances of 5 herbaceous species on the Western Shore were correlated with one or more of the isolation indices (Table 8). There was no pattern in the sign of the correlation coefficients on the Western Shore (4 positive, 3 negative), but on the Eastern Shore 5 of the 6 significant correlations with isolation were negative. In general, the number of significant species-level correlations with isolation was sufficiently small to be attributed to chance.

Area (LAR) — Few plant species responded significantly to forest area, but those which did respond generally were more abundant in larger forest patches (8 of 11 instances). No species responded significantly to area on both shores.

Tree density (FDT) — The local abundances of 12 tree and shrub species were significantly correlated with FDT, but no herbaceous species were so correlated (Table 8). On the Western Shore, 7 of 8 species showed a negative response to FDT; on the Eastern Shore, 2 species showed positive and 2 species showed negative correlations.

Abundance of pines (PIN) — the local abundances of three tree species were negatively correlated with PIN (Table 8). A total of 6 species of Western Shore herbs and shrubs were positively correlated with PIN; on the Eastern Shore, 2 of 3 significant species-level correlations with PIN were negative. Only one herb species (Mitchella repens) was significantly correlated with PIN on both Shores.

Canopy height — As can be seen in Table 8, more plant species (18) responded to canopy height than to any other independent variable except the isolation indices. On the Western Shore, 4 tree species were negatively correlated with canopy height. These may be species that are more common on drier, sub-optimal sites where canopy height is lower. Carya and Liriodendron showed positive correlation coefficients with CHT, indicating that they may be more important components of the taller forests characteristic of mesic sites. Importance values of two taller understory trees (Sassafras, Cornus) were also correlated with canopy height. Sassafras, an early successional species, had a negative correlation coefficient, while Cornus, a typical understory species of mature mesic forests, had a positive correlation coefficient. Among the shrub species of lower stature, Leucothoe was positively correlated with CHT, while Clethra and two species of Vaccinium were negatively correlated. Among the herbs, Parthenocissus and Chimaphila were significantly more abundant in lower stature forests, while Mitchella, Arisaema, and Circaea showed the opposite response.

DISCUSSION

I. Bird populations: Importance of Forest Area vs. Other Factors

The analogizing of habitat patches and oceanic islands has caused biologists to scrutinize the relationship between the area of forest tracts and the diversity and abundance of associated organisms. Workers in Europe (Oelke, 1966), England

(Moore and Hooper, 1975), Wisconsin (Bond, 1957), Delaware (Linehan et al., 1967), New Jersey (Galli et al., 1976; Forman et al., 1976), and in the Piedmont area of Maryland and adjacent states (Robbins, 1980; Whitcomb et al., 1981) have reported effects of habitat fragmentation on forest-associated birds. Comprehensive evaluation of the results of these studies is difficult, as most earlier workers considered only a small number or limited size range of forest patches, and most have failed to assess such potentially important patch characteristics as isolation, floristics, and forest physiognomy.

Some studies (e.g., Oelke, 1966; Linehan et al., 1967) have emphasized the increase in total bird numbers in smaller forest patches; others (e.g., Moore and Hooper, 1975; Galli et al., 1976; Forman et al., 1976; Robbins, 1979, 1980; Whitcomb et al., 1981) have focused attention on the relationship between bird species composition and patch area. Only Robbins (1980) has statistically analyzed the relative contributions of habitat factors and isolation, as well as area, on bird community composition. Employing a similar approach to that used in the present study, Robbins used multiple regression analysis to quantify the effects of area, isolation, and forest structure on the local abundance of individual bird species in 67 forest islands located in the Piedmont of Maryland, Pennsylvania, Virginia, and West Virginia. His results indicate that canopy height and forest isolation were the most consistently important predictors of the abundances of 51 analyzed bird species, accounting for a total of 21 significant correlations. Patch area per se accounted for only 6 significant correlations, although a related variable (distance from census point to edge of patch) contributed 10 additional significant correlations. In the same paper, Robbins (1980) reported the results of a second regression analysis on data from 80 breeding bird census plots in the northeastern U.S. This analysis revealed that the area of contiguous habitat showed the highest

number of statistically significant correlations with individual species abundances. However, because this second analysis did not include patch isolation as a predictor variable, the inconsistency in the results with respect to the primacy of patch area as a predictor of bird abundance may be more apparent than real.

Thus, although a number of previous studies have reported a significant relationship between forest area and species composition of the associated avifauna, the only study that attempted a quantitative statistical analysis of the relative importance of other factors in addition to area yielded ambiguous results. The fundamental problem appears to stem from the intercorrelation of patch area with other habitat variables which themselves may be more important to some bird species than is area.

The results of the present study are especially valuable in addressing the question of which habitat variables are of major importance in predicting the occurrence of particular bird species. In general, our results are in accord with those reported by Robbins (1980) for his 67 Piedmont woodlots. Patch isolation (ISA, ISB, ISC), forest physiognomy (BAF, CHT, FDT, PCC), and floral diversity (HDE, SDE, TDE, TPS) together accounted for 48 of 66 (73%) statistically significant correlations with individual bird species abundances. Patch area (LAR) was significantly correlated with only 8 species abundances, and three of these correlations were negative (i.e., three species were more abundant in smaller patches). For only one species (Kentucky Warbler), was area the most important single predictor of local abundance (Table 4). Similarly, Ovenbird was the only species for which a negative correlation with one of the three isolation factors was the most important predictor of abundance. In contrast, measures of forest physiognomy or plant richness were the most important single determinants of abundance for 19 species. Thus, within the range of forest area (generally > 5 ha)

and isolation (generally < 1 Km from nearest large forest patch) considered here, habitat characteristics, rather than area or isolation, appear to play the major role in determining community composition and the local abundance of individual species.

The conclusion by earlier workers that area per se is the key patch characteristic that determines occurrence of many migrating bird species is valid for some species (e.g., Kentucky Warbler) and in some regional habitat configurations (e.g., landscapes that feature small, highly isolated forest tracts). However, it also seems likely that some of the previous tendency to emphasize area as the key habitat factor stems from an incomplete understanding of the complex intercorrelations among area, isolation, canopy height, tree density, and other variables. In the present study, forest area showed highly significant ($p < .01$) simple correlations with ISC, ISB, and PCC, i.e., small forest tracts also tended to be highly isolated and possess a relatively dense canopy. Formal statistical analysis reveals that these latter features, rather than area itself, often influence bird occurrences. Small forest tracts do tend to support few or no individuals of certain bird species, but in many instances the species in question appear to respond to other habitat features that themselves are correlated with area.

Another feature of our study that may have resulted in areas having relatively low importance as an independent predictor of species occurrences is the relatively low degree of isolation of forest patches on the Maryland coastal plain (Table 2), as opposed to the nearby Piedmont area studied by Robbins (1980) and Whitcomb et al. (1981). The latter authors presented evidence that even fairly small patches can maintain a reasonably complete avifauna, provided isolation from an extensive "mainland" source area is sufficiently low. In our study, the average distance to the nearest patch of at least 50 ha (ISB) was about 0.4 Km, whereas in

the Piedmont area studied by Robbins (1980), the equivalent figure (actually to the nearest 40 ha patch) was 4.7 Km, or about ten times as great (C. S. Robbins, pers. comm.).

Finally, some bird species may combine area-sensitivity with rarity, such that statistically significant trends will be difficult to detect even with a relatively large sample of tracts. A case in point is Worm-eating Warbler, a relatively uncommon species that has been identified as area-sensitive in earlier studies in the middle Atlantic Piedmont region (Robbins, 1980; Whitcomb et al., 1981). This species was encountered in only 15 of the 185 tracts where we conducted both point surveys and vegetation studies. As a result, our data for this species are dominated by an excessive number of "zero" entries. In such situations, non-parametric analysis of occurrence patterns, using presence-absence data, will be more appropriate than our regression-correlation approach. Although multiway contingency analysis was not attempted, due to non-availability of the proper computer programs, a binomial test of the significance of differences in the percentage of small tracts where Worm-eating Warbler occurred ($2/217 = 0.9\%$ of all tracts $\leq 35 \text{ ha}^2$ where point surveys were conducted) vs. the percentage occurrence in larger tracts ($26/207 = 12.6\%$ of tracts $> 35 \text{ ha}$ where point surveys were conducted) revealed a highly significant ($p < .01$) association of the species with larger tracts. This relationship might have emerged from our correlation analysis if a sufficiently large number of very large tracts had been sampled (we surveyed only 14 tracts that exceeded 1,000 ha). However, the few extant tracts of this size in our study area tend to be highly disturbed successional woods.

With the foregoing caveats in mind, we would nevertheless concur with the view put forth by Bond (1957), and seconded by Whitcomb et al. (1981), that habitat quality and habitat area are to some extent compensatory in their effects on bird

species occurrences. Above some critical minimum patch area, moderately sized, but floristically and physiognomically "rich" forest patches may support bird communities that are similar to those that inhabit larger, but "poorer" forests. We would add patch isolation as another important compensatory factor, but hasten to emphasize that these various habitat characteristics are not completely interchangeable for any species, and may not be interchangeable at all for some. Thus, certain bird species never inhabit very small, highly isolated patches, no matter how "rich" the forest may be. A related problem is the possibly discontinuous nature of some of our predictor variables. It is possible, for example, that two forest patches are not perceived by birds as being functionally isolated unless the distance separating them exceeds some minimum threshold value. In our analysis we considered forests as being dissected if they were interrupted by roadways or other openings at least 10 m wide, although most of our tracts were isolated by distances that were orders of magnitude greater than this value (Table 2). The main error that might be introduced by our admittedly conservative definition of isolation would be the tendency to underestimate the functional area of forest tracts as perceived by birds. This in turn might blur the distinctions between the avifauna of smaller vs. larger forest patches.

II. Habitat Disruption vs. Migratory Strategies.

The results of the present study confirm and extend earlier suggestions (e.g., Lynch and Whitcomb, 1978; Greenberg, 1980; Robbins, 1980; Whitcomb et al., 1981) that long-distance avian migration is associated with a characteristic suite or syndrome of biological characteristics, including high responsiveness to habitat disruption (e.g., reduced forest area, increased isolation, decreased floristic and physiognomic richness. Of 18 significant correlations that involve the local density of individual neotropical migrant species and forest area or forest isolation, 14 were

in the predicted direction (i.e., positive correlation with LAR, negative correlation with ISC, ISB, ISA). The common short-distance migrants and permanent resident species showed a very different pattern. Although the total number of species was nearly as great (14) as the number of common neotropical migrants (16), the resident and short-distance migrant species showed only 8 significant correlations involving forest area or isolation, and 6 of these had signs opposite those predicted for the neotropical migrants. Thus, species that are not highly migratory either showed no response to patch area and isolation (within the range of patch characteristics we studied), or actually attained higher densities in tracts that were smaller or more isolated, or both. Our results document a tendency for forest-associated neotropical migrants to respond positively to what ecologists commonly view as "quality" habitat factors. Thus, a total of 21 statistically significant correlations of individual species abundances with measures of forest stature and floristic complexity (BAF, CHT, HCT, NSD, HDE, SDE, TDE, TPS) involved 15 of the 16 neotropical migrant species we studied in some detail. Importantly, the signs of these correlations are not arbitrary: neotropical migrants tended to be more abundant in forests where plant diversity is higher (8 of 10 significant correlations positive) and where the forest is tall with well-developed herb and shrub layers (7 of 11 significant correlations positive).

In contrast, short-distance migrants and permanent residents tended to show correlations of opposite signs with indicators of forest stature and diversity, or to be uncorrelated with these factors. Thus only 16 significant correlations involved permanent residents and short-distance migrants (vs 21 for neotropical migrants). Of the 6 correlations involving plant diversity factors, 5 were negative.

Early successional forests (characterized by high values for PIN and FDT, and low values for CHT and BAF) were utilized at least to some degree by all three

migratory groups, but they were not usually the preferred habitat. Among the neotropical migrant species, 7 of 13 significant correlations of abundances with the named variables has signs that indicate higher abundance in more mature forest. Short-distance migrants and permanent residents showed a similar response to forest maturity: 6 of 9 significant correlations had signs indicating preference of species for more mature forest.

The causal mechanisms by which migratory strategy interacts with habitat preference remain undefined, but Greenberg (1980) and Whitcomb et al. (1981) have suggested that demographic differences between migratory groups may explain some of the observed differential responses to habitat disruption. Present data are insufficient to resolve this issue, but some or all of the following demographic characteristics of neotropical migrants may be related to their sensitivity to habitat degradation: low clutch size, low incidence of multiple clutches per breeding season, tendency to build open nests that are placed on or near the ground, tendency for young birds to disperse out of their home area following fledging. This last feature, which might in turn cause first year birds to "miss" their home forest patch when they return to breed following their first neotropical migration, has been discussed by Whitcomb et al. (1981), and mathematically modelled by May (1981).

III. Implications for Conservation and Management

Results of the present study are relevant to the regional conservation and management of bird populations, but broad generalizations must be tempered by recognition of the ecological uniqueness of each species. At a very general level, this study is a confirmation and quantification of what most experienced field ornithologists would have predicted all along - every bird species responds to a different combination of habitat features (e.g., James, 1971; Anderson and Shugart,

1974; Anderson, 1979). Because the "niche gestalt" (James, 1971) of each species is in some ways unique, no single management intervention will benefit all species, and almost any conceivable "habitat enhancement" strategy will have negative impacts on a number of species.

For some local birds (e.g., Kentucky Warbler, Ovenbird) the geographic configuration of habitat patches seems to be of paramount importance, and factors such as patch area and isolation importantly influence local breeding densities. For a larger group of species, local density is not a simple continuous function of forest area or isolation, but is strongly dependent on details of habitat physiognomy and floristics. Of course, no species is free from the ultimate constraints of forests that are too small to support minimal territorial requirements. However, many small passerines do not appear to be markedly restricted by the existing pattern of forest patch area and isolation in eastern Maryland, at least for patches that exceed 5-10 ha. If we had considered woodlots of much smaller size, or if we had studied an area where average isolation of forest patches is greater (e.g., the Piedmont of Maryland or New Jersey) our results might have been very different (Galli et al., 1976; Forman et al., 1976; Robbins, 1980).

The ecological truism that each species is in some ways unique does not mean that meaningful patterns do not exist in the responses of birds to habitat degradation. If, for example, attention is focused on the neotropical migrants, a group which is of increasing concern to conservationists (Lynch and Whitcomb, 1978; Keast and Morton, 1980; Morton, 1980; Robbins, 1980; Whitcomb et al., 1981), a consistent syndrome of responses to habitat disturbance is evident. Highly migratory species tend to show negative responses to habitat fragmentation (reduction of habitat area, increased isolation of remaining habitat) and reduction of floristic and structural diversity of breeding habitat. This pattern will be

obscured if all migratory categories and habitat associations are indiscriminately combined in an analysis, for the same factors that depress populations of neotropical migrants tend to favor permanent resident and short-distance migrant species. The latter two groups are often tolerant of disturbed and "edge" conditions as well as forest-interior habitats (Anderson, 1979; Lynch and Whitcomb, 1978; Whitcomb et al., 1981). Examples of sedentary or only partially migratory habitat generalists include some of the commonest "backyard" suburban birds (e.g., Carolina Chickadee, Gray Catbird, Blue Jay, Rufous-sided Towhee), none of which is in danger of regional extinction or serious decline. Such species, despite their considerable ecological importance and intrinsic interest, are of limited conservation concern (Anderson, 1979; Noon et al., 1979; Whitcomb et al., 1981).

The total diversity of bird species actually increases slightly in smaller tracts, as does bird density (see Table 4; also Linehan et al., 1967; Oelke, 1966), but the influx of abundant, ecologically generalized resident and short-distance migrant species mainly accounts for this increase. We therefore emphasize the importance of avoiding a simplistic "numbers game" when assessing the impact of habitat disruption on birds and other organisms. Just as bird species differ in their ecological requirements, they also differ in their resiliency in the face of disturbance, and hence in their conservation importance. The arrival in the U.S. of the introduced European Starling (Sturnus vulgaris) and House Sparrow (Passer domesticus) did not in any meaningful sense compensate the loss of the Passenger Pigeon (Ectopistes migratorius) and Ivory-billed Woodpecker (Campephilus principalis).

We emphasize that the point survey method employed in the present study is a sampling technique, not an exhaustive censusing method. It yields a quantitative estimate of bird density and diversity in the vicinity of the survey point, but not a

total count of individuals and species in an entire forest patch. A practical result of this limitation is that the point survey method will almost inevitably underestimate the true differences between the total avifauna of very small tracts (which may be adequately sampled by a single set of point surveys) and a large tract (which will be severely undersampled, even if two or three points are surveyed). Species that are locally more abundant in small wooded tracts may nevertheless be far less common regionally than they were prior to extensive deforestation. The Downy Woodpecker, a common permanent resident in the study area, is a case in point. The local density of Downy Woodpecker is negatively correlated with the natural logarithm of forest area ($r = -.19$; $p < .01$), but the slope of the relationship is fairly low ($b = -.039$). If we imagine that deforestation reduces a previously continuous 30 ha woodland to a 10 ha remnant, the predicted local density of Downy Woodpecker in the remaining forest would be about 4% above the original level. However, this would not come close to compensating the reduction by nearly two-thirds of the total population of Downy Woodpecker resulting from the loss of 20 ha of habitat. On the other hand, it could be argued, at least from the point of view of a Downy Woodpecker, that three 10 ha woodlots might be slightly preferable to one continuous 30 ha tract. This of course would not be true for species like Kentucky Warbler, which show a significant positive local density response to woodland area. Our data suggest that, above some critical minimum patch size, any correlations between local point density and the area of individual forest patches tend to be outweighed by the effects of the quality and total extent of suitable habitat in a region. This implies that for certain species the best regional conservation strategy may be to preserve the maximum total amount of breeding habitat, without overly emphasizing the extent of each individual forest fragment. This strategy would be valid only if all of the

conserved patches were large enough or in close enough proximity (or both) to be acceptable as breeding sites for target species (Galli et al., 1976; Forman et al., 1976; Robbins, 1980; Whitcomb et al., 1981). This strategy does not assume, as do previous recommendations by Lynch and Whitcomb (1978), Robbins (1980), and Whitcomb et al. (1981), that each patch in an avifaunal preserve must be sufficiently large to independently support stable long-term populations of all target species. The latter goal is an ideal that should be strived for where possible (e.g., Amazonia). However, it is unrealistic to consider the heavily fragmented archipelago of forest patches that typifies the eastern U.S. coastal corridor in anything other than a regional context. Although preserves of thousands of hectares of contiguous old growth forest are indeed optimal for many (perhaps most) conservation purposes, such enormous tracts no longer exist in many settled regions. Even in those areas where very large contiguous tracts of land can still be acquired, it may be that a closely spaced network of somewhat smaller tracts of greater aggregate area will better serve at least some conservation purposes. Such a network of preserves might, for example, be better protected against catastrophic disruptions, might be less expensive to purchase, and might be more easily justified politically. Although very small forest tracts (of the order of 1 - 4 ha) may have little or no conservation value for most birds, we believe that a closely spaced series of somewhat larger tracts (10 - 50 ha) can play a useful role in conserving certain regionally endangered bird species, given the existing land use pattern in coastal Maryland. However, if average inter-patch isolation increases and the aggregate area of forest decreases substantially, more and more of the total regional breeding activity of uncommon species will be concentrated in remaining large tracts. Under these conditions, which would approach literal insularity, much larger reserves would be necessary than present land-use

conditions appear to require in our study area. Some bird species (e.g., Worm-eating Warbler) already are facing dramatic regional contraction of their former breeding range in the Maryland piedmont, immediately to the west of the present study area (Robbins, 1979, 1980). In the latter area, it appears that extensive deforestation has so reduced the number and size of wooded tracts, while simultaneously increasing their isolation, that the Worm-eating Warbler is precluded from breeding in much of the area.

Our results indicate that even a slight degree of habitat isolation importantly influences bird species occurrences in forest patches. This may seem surprising, in view of the long-distance migratory flights undertaken annually by many local species. The apparent aversion of many birds, particularly neotropical migrants, to isolated forest tracts may represent a "psychological" avoidance of adjacent open habitats. Alternatively, the observed pattern may reflect the relatively deep penetration of isolated forests by edge-related physical conditions and edge-adapted predators, competitors, and nest-parasites (Gates and Gysel, 1978; Gates and Mosher, 1981; Lynch and Whitcomb, 1978; Ranney et al., 1981; Thomas, 1980; Whitcomb et al., 1981). Whatever their ultimate causes, both positive and negative density responses to forest isolation are widespread in the local bird community (Table 4). Familiar migratory species such as Red-eyed Vireo and Wood Thrush experience a mean decline of about 2% in their local density with each 100m of isolation. Thus, creation of non-forested corridors with widths of the same order of magnitude as a major powerline right of way or multi-lane highway could have a small, but statistically significant, depressing effect on local population levels of some bird species, particularly neotropical migrants.

The strong responses of many bird species to what may be loosely termed "habitat quality factors" might be interpreted as an indication that habitat

modification would be an effective management tool in certain local situations. For example, creation of small canopy openings through selective tree removal might benefit such species as Blue-gray Gnatcatcher. However, even this relatively simple manipulation might be prohibitively expensive if conducted on the geographic scale required for a regional preservation strategy. In addition, most of the habitat "quality" factors that favor neotropical migrants (e.g., increased plant species diversity, increased canopy height, increased dbh values for trees) are associated with older growth forest. Such factors cannot be effectively manipulated except on a very long-term basis. Thus, the main practical management implications of our data will involve the avoidance of detrimental interventions (e.g., reduction of forest area, increase of isolation, removal of understory vegetation) that have been shown to be impact target species of special conservation interest (e.g., Kentucky Warbler, Worm-eating Warbler, Yellow-throated Vireo).

IV. Effects of Habitat Fragmentation on Plants

There are few published data on the impact of landscape dissection on plant species diversity in forest patches, although consideration has been given to the sizes and numbers of areas needed to optimize plant diversity in reserves (Higgs and Usher 1980; Game and Peterken, 1981). Old-growth woodlots may function as refugia for plant species that are sensitive to disturbances, but the recolonization of forest patches by species that were extirpated by disturbances or natural causes (e.g., pest outbreaks) has not been studied. Forman and his colleagues at Rutgers studied the distribution of several groups of organisms among forest patches in New Jersey. They were able to demonstrate forest area-diversity relationships for birds (Forman et al., 1976; Galli et al., 1976), but, as in the present study, clear patterns did not emerge for plants. They did find that a nearby relatively large undisturbed

forest had a higher diversity of woody species than the forest patches sampled, but they failed to demonstrate any clear relationships between number of plant species and forest area. In an unpublished study of tree diversity in a small number of isolated woodlots in Ohio, D. E. Suhrweir and E. J. Tramer found that area and isolation together accounted for approximately 75% of the variation in tree species number, and that the percentage of explained variance increased to nearly 95% when the woodlots were sorted by soil type. Their results, therefore, would appear to contradict those of Forman et al. (1976) in New Jersey, although only forest area was considered in the latter study.

Our results, which are based on uniform sampling intensity per patch (rather than exhaustive censuses of each patch) were more similar to those of Forman et al., even though we sampled many more forest tracts and considered additional predictor variables. Community variables (e.g., species diversity) showed significant correlations with measures of forest area, isolation, and physiognomy, but few significant correlations linked the occurrence of individual species with these same predictors. This pattern is opposite to that found for birds in the same forest patches, where individual species were more responsive than were community properties to patch characteristics. For plants, the multiple regression equations accounted for only a small proportion of the total variance in either community or individual species characteristics. Forest vegetation is influenced by very long-term interactions of a great many local sites factors. Although island-biogeographic concepts have proved useful in predicting the richness of plant communities associated with highly isolated, very small, artificially planted, and relatively recent forest patches (Scanlan, 1981), "blunt" predictors such as patch area and isolation appear to have little predictive value in the analysis of older, more complex landscape of regenerating natural forests in our study. Plant

community variables are more predictable than individual species occurrences, but the geometric factors that are most important in island biogeographic theory do not appear to be of paramount importance in determining local forest composition, at least within the range of areas and isolations that were considered in the present study.

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Table 1. Classification of 270 forest patches sampled in this study according to vegetation types defined and mapped by Brush et al. (1980). Values in the tables are numbers of forest patches that occur in the associations listed as follows: TP = Tulip Poplar, C-P-B = Chestnut Oak - Post Oak - Blackjack Oak, BO = Basket Oak, B-L = Basket Oak - Loblolly Pine, W-L = Willow Oak - Loblolly Pine, RB-S = River Birch - Sycamore.

County	TP	C-P-B	BO	B-L	W-L	RB-S
Western Shore						
Anne Arundel	36	10	15	-	-	-
Prince Georges	63	20	-	-	-	-
Charles	16	16	-	2	16	2
TOTAL	115	46	15	2	16	2
Eastern Shore						
Kent	11	-	2	7	2	-
Queen Annes	-	-	3	15	14	-
Talbot	-	-	-	17	3	-
TOTAL	11	0	5	39	19	0

Table 2. Summary statistics for forest patches on the Western (n = 169) and Eastern (n = 74) Shores. Variables are described on pages 12 - 13.

Variable	<u>Western Shore</u>		<u>Eastern Shore</u>	
	Mean	SD	Mean	SD
LAR	3.42	1.34	2.92	1.33
ISC	11.61	13.18	30.38	19.17
ISB	3.17	6.30	12.74	15.63
ISA	7.39	11.13	18.01	19.53
CHT	24.34	8.69	23.11	9.70
PCC	59.34	18.62	65.94	25.04
BAF	29.36	9.59	29.24	11.12
FDT	555.18	179.77	534.69	191.67
NSD	31,653	14,012	24,900	14,262
HCT	5.47	4.05	2.66	2.86
PIN	2.34	7.74	20.96	29.42
TPS	44.65	14.74	32.44	12.51
TDE	8.52	3.13	7.55	2.89
SDE	18.36	5.77	13.97	6.17
HDE	9.04	5.47	5.03	4.08

Table 3. Significant responses of bird community characteristics to predictor variables. * = $p < .05$; ** = $p < .01$; *** = $p < .001$ (see text for description of variables).

Community Characteristic	Code	Western Shore	Eastern Shore	Combined
Total bird species	TBS	PIN* (neg), ISB* (neg)	LAR*** (neg), CHT* (neg), HCT* (neg)	LAR** (neg)
Total number of pairs of birds	TPB	ISA** (neg), HCT**, NSD*	LAR** (neg)	HCT***, ISA** (neg), LAR* (neg)
Exponential species diversity	BDE	FDT** (neg)	None	FDT** (neg)
Total forest-interior species	FSP	HDE**, ISA** (neg)	None	
Total forest-interior pairs	FPR	HCT***, ISA*** (neg), BAF***	ISB* (neg)	
Total edge-field species	ESP	LAR*** (neg), CHT (neg)*	LAR*** (neg), HCT**, CHT*	
Total edge-field pairs	EPR	LAR*** (neg), PCC* (neg), BAF* (neg)	LAR*** (neg), TPS*, CHT*	

Table 4. Significant responses of individual bird species to predictor variables.
Data combined for both shores of Chesapeake Bay.

Family Species ^a	Significant Predictors	R ^b
Neotropical Migrants		
Cuculidae		
YBCU	TPS (neg)***, ISC***, ISA (neg)***	.42***
Trochilidae		
RTHU	SDE*	.17*
Tyrannidae		
ACFL	TPS***, ISC (neg)***	.64***
EWPE	CHT***, LAR (neg)*	.26**
GCFL	ISC***, HCT (neg)**, PIN**	.57***
Turdidae		
WOTH	ISB (neg)***, ISC**, CHT**, BAF**	.44***
Parulidae		
BAWW	BAF (neg)***, ISC (neg)*, LAR*	.38***
HOWA	TPS**, LAR**, ISC (neg)*, FDT (neg)*	.45***
KEWA	LAR***, HCT**, SDE (neg)*, FDT (neg)*	.39***
NOPA	TPS***, LAR**	.43***
OVEN	ISC (neg)***, FDT***, SDE***, HCT*	.53***
WEWA	PIN***, ISB (neg)**	.32***
Vireonidae		
REVI	TPS***, PIN (neg)***, ISC (neg)**, LAR**	.65***
WEVI	HCT**, BAF (neg)**	.27**
YTVI	SDE**, ISC (neg)**	.29***
Thraupidae		
SCTA	SDE**, PIN (neg)*	.33***

^a Complete list of scientific names, common names, and species mnemonics given in Appendix E.

^b Coefficient of multiple correlation; significance levels: * $p < .05$; ** $p < .01$; *** $p < .001$.

Table 4. (Continued)

Family Species ^a	Significant Predictors	R ^b
Short-distance Migrants		
Picidae		
COFL	ISC***, TPS (neg)**	.45***
Mimidae		
GRCA	LAR (neg)***, SDE (neg)**, PIN (neg)*	.36***
Corvidae		
BLJA	TPS (neg)***, ISC**, NSD**, CHT*	.54***
Parulidae		
PIWA	PIN***, PCC (neg)*, SDE*	.64***
Sylviidae		
BGGN	PCC (neg)**, ISB (neg)**	.30***
Fringillidae		
RSTO	FDT**, TDE (neg)*	.26**
Permanent Residents		
Picidae		
DOWO	LAR (neg)**, PIN**, ISC (neg)**, CHT*	.25**
HAWO	ISB***	.26***
PIWO	None	-
RBWO	BAF***, FDT (neg)***	.39***
Troglodytidae		
CAWR	ISA**	.24**
Sittidae		
WBNU	CHT***	.25***
Paridae		
CACH	SDE (neg)**	.20**
TUTI	PCC (neg)*	.15*
Fringillidae		
CARD	HCT***, NSD (neg)**	.47***

Table 5. Number of species showing significant ($p < .05$) positive or negative correlations with 15 predictor variables. The variable showing the highest partial correlation for each species is given in line b : ("Primary Vbl").

Migratory group	Predictor Variables																
	LAR	ISC	ISB	ISA	BAF	CHT	FDT	PCC	HCT	NSD	PIN	HDE	SDE	TDE	TPS		
Neotropical migrants																	
a. total	5,1	3,5	0,2	0,2	2,2	2,0	1,2		3,1	0,1	2,2		4,1			4,1	
b. primary Vbl	1,0	1,0	0,1	0,1	0,1	1,0			1,0		1,0		3,0			4,1	
Short distance migrants																	
a. total	0,1	2,0	0,1		1,0	1,0	1,0	0,2		1,0	1,1		1,1	0,1		0,2	
b. primary Vbl	0,1	1,0				1,0	1,0	0,1			1,0					0,1	
Permanent residents																	
a. total	0,1	0,1	1,0	1,0	1,0	2,0	0,1	0,1	1,0	0,1	1,0		0,1			0,1	
b. primary	0,1		1,0	1,0	1,0	1,0		0,1	1,0								
All species																	
a. total	5,3	5,6	1,3	1,2	3,2	5,0	2,3	0,3	4,1	1,2	4,3	0,0	5,3	0,1		4,3	
b. primary Vbl	1,2	2,0	1,0	1,1	1,1	2,0	1,0	0,1	2,0	0,0	2,0	0,0	3,1	0,0		4,2	

Table 6. Summary of patterns of association between bird species abundances and functional groups of predictor variables.

Functional Group	Individual Variables	Number and Percentage of Species Showing Significant Correlations				Total* (n = 30)
		Neotropical migrants (n = 16)	S-D migrants (n = 6)	Residents (n = 8)		
Patch area	LAR	6 (38)	1 (17)	1 (13)	8 (27)	
Patch isolation	ISA, ISB, ISC	10 (63)	3 (50)	3 (38)	16 (53)	
Tree physiognomy	BAF, CHT, FDT, PCC	8 (50)	4 (67)	4 (50)	16 (53)	
Understory physiognomy	HCT, NSD	3 (19)	0 (0)	1 (13)	4 (13)	
Pine abundance	PIN	4 (25)	2 (33)	1 (13)	7 (23)	
Plant diversity	HDE, SDE, TDE, TPS	10 (63)	5 (83)	1 (13)	16 (53)	
<u>Summary</u>						
Median number significant predictors per species		2.9	2.7	1.6		
Median value of R (multiple correlation coefficient)		.40	.40	.25		

* does not include Pileated Woodpecker, which showed no significant correlations.

Table 7. Results of stepwise multiple regression analysis for community-level response variables for the Western Shore and Eastern Shore vegetation. Variables with significant regression coefficients and their signs (negative = NEG, positive = POS) are given. Significance levels: * = 0.05, ** = 0.01, *** = 0.001. R is the multiple correlation coefficient. Variables are described in the text.

Community-level Variable	Western Shore	R
TPS	CHT (POS)** , ISA (NEG)*	.387
TTS	-	-
TSS	-	-
THS	CHT (POS)*** , PIN (NEG)*	.453
TDE	ISB (POS)** , ISA (NEG)*	.303
SDE	-	-
HDE	LAR (POS)***	.381
FDT	ARE (NEG)*** , ISB (NEG)** ISC (POS)*	.470
NSD	LAR (NEG)**	.387
HCT	LAR (POS)*** , ISB (POS)* , (PIN (NEG)*	.468
BAF	LAR (POS)***	.759
PCC	ISC (POS)*** , ISA (NEG)*	.316
Eastern Shore		
TPS	PIN (NEG)* , ISC (NEG)*	.483
TTS	ISC (NEG)**	.190
TSS	ISA (NEG)** , ISC (NEG)**	.490
THS	PIN (NEG)***	.430
TDE	ISC (NEG)**	.321
SDE	ISC (NEG)** , PIN (NEG)*	.293
HDE	PIN (NEG)***	.440
FDT	PIN (POS)*** , LAR (NEG)**	.581
NSD	ISB (NEG)**	.435
HCT	PIN (NEG)**	.379
BAF	PIN (POS)*** , LAR (POS)** , ISA (POS)*	.593
PCC	LAR (NEG)* , PIN (NEG)*	.590

Table 8. Results of stepwise multiple regression analysis for species-level variables for the Western Shore and Eastern Shore. Variables with significant regression coefficients are given along with the sign (negative = NEG, positive = POS) of the coefficient. Significance levels: * = 0.05, ** = 0.01, *** = 0.001. R is the multiple correlation coefficient. Variables are described in the text.

Species	Western Shore	R	Eastern Shore	R
<u>TREES</u>				
<i>Acer rubrum</i>	CHT (NEG)*	.281		
<i>Carpinus caroliniana</i>	FDT (NEG)**	.642		
<i>Carya glabra</i>			ISCA (POS)*	.562
<i>Carya ovata</i>	CHT (POS)*	.709		
<i>Liquidambar styraciflua</i>	PIN (NEG)*, ISA (POS)*	.302		
<i>Liriodendron tulipifera</i>	CHT (POS)***	.588		
<i>Nyssa sylvatica</i>	FDT (NEG)**	.330	ISB (POS)*, PIN (NEG)*	.318
<i>Pinus virginiana</i>	FDT (POS)***, CHT (NEG)*	.554		
<i>Quercus alba</i>	CHT (NEG)***, LAR (POS)*	.243		
<i>Quercus coccinea</i>	LAR (POS)*	.722	ISB (NEG)**	.356
<i>Quercus falcata</i>	CHT (NEG)*	.351		
<i>Quercus michauxii</i>			FDT (NEG)**	.539
<i>Quercus phellos</i>			FDT (NEG)**	.423
<i>Quercus rubra</i>	ISC (POS)**	.377	PIN (NEG)*	.373
<i>Quercus velutina</i>			LAR (NEG)**	.400
<i>Ulmus</i> sp.			CHT (NEG)*	.964

Table 8. (Continued)

Species	Western Shore	R	Eastern Shore	R
<u>SHRUBS</u>				
<i>Aralia spinosa</i>	LAR (POS)*	.424		
<i>Carpinus caroliniana</i>	ISB (NEG)*, FDT (POS)*	.358		
<i>Clethra alnifolia</i>			PIN (POS)** , CHT(NEG)*	.449
<i>Cornus florida</i>	CHT (POS)** , ISB (POS)*	.550		
<i>Diospyros virginiana</i>			ISA (POS)**	.322
<i>Euonymus americana</i>	ISB (POS)** , ISC (NEG)*	.346		
<i>Gaylussacia baccata</i>			LAR (POS)*	.567
<i>Ilex opaca</i>			ISB (POS)**	.573
<i>Juniperus virginiana</i>			FDT (POS)*	.718
<i>Kalmia latifolia</i>	FDT (NEG)*	.516		
<i>Leucothoe racemosa</i>			CHT (POS)** , ISC (POS)*	.522
<i>Lindera benzoin</i>	FDT (NEG)*	.507	ISC (POS)*	.816
<i>Pyrus americana</i>	PIN (POS)** , ISC (POS)* , FDT (NEG)*	.669	ISA (POS)**	.429
<i>Rhododendron maximum</i>			FDT (POS)** , PIN (NEG)**	.841
<i>Rhododendron nudiflorum</i>	LAR (POS)*	.516		
<i>Sassafras albidum</i>	ISC (NEG)** , CHT (NEG)*	.373		
<i>Vaccinium atrococcum</i>	ISC (POS)** , FDT (POS)* , ISC (NEG)*	.473		
<i>Vaccinium corymbosum</i>	PIN (POS)**	.524	CHT (NEG)** , LAR (POS)*	.508
<i>Vaccinium vacillans</i>	CHT (NEG)* , PIN (POS)*	.375		
<i>Viburnum acerifolium</i>	FDT (NEG)**	.469		
<i>Viburnum dentatum</i>			ISB (POS)**	.477
<i>Viburnum prunifolium</i>			LAR (NEG)* , PIN (NEG)*	.685

Table 8. (Continued)

Species	Western Shore	R	Eastern Shore	R
	<u>HERBS</u>			
<i>Arisaema triphyllum</i>	CHT (POS)*	.586		
<i>Botrychium dissectum</i>	LAR (POS)**	.812		
<i>Campsis radicans</i>	ISC (POS)**	.959		
<i>Chimaphila maculata</i>	ISC (POS)***, CHT (NEG)**	.720		
<i>Circaea lutetiana</i>	CHT (POS)**	.539	ISA (NEG)*	.635
<i>Dennstaedtia punctiloba</i>				
<i>Desmodium nudiflorum</i>	PIN (POS)**, LAR (POS)*	.615		
<i>Lonicera japonica</i>	ISC (NEG)*	.308		
<i>Lycopodium obscurum</i>			PIN (POS)*	.756
<i>Mitchella repens</i>	PIN (POS)***	.492	CHT (POS)***, PIN (POS)***, ISA (NEG)*	.764 ⁵⁰ .764 ⁵¹
<i>Oxalis</i> sp.	ISA (POS)***, PIN (POS)**	.933		
<i>Panicum dichotomum</i>	ISC (NEG)*	.627		
<i>Parthenocissus quinquefolia</i>	LAR (NEG)*	.361	CHT (NEG)*	.468
<i>Phryma leptostachya</i>	ISA (POS)**, ISC (NEG)*	.815		
<i>Rhus radicans</i>			ISB (NEG)***, ISA (POS)***	.758
<i>Rubus</i> sp.	ISC (NEG)***	.423		
Unidentified grass	ISC (NEG)***	.795		

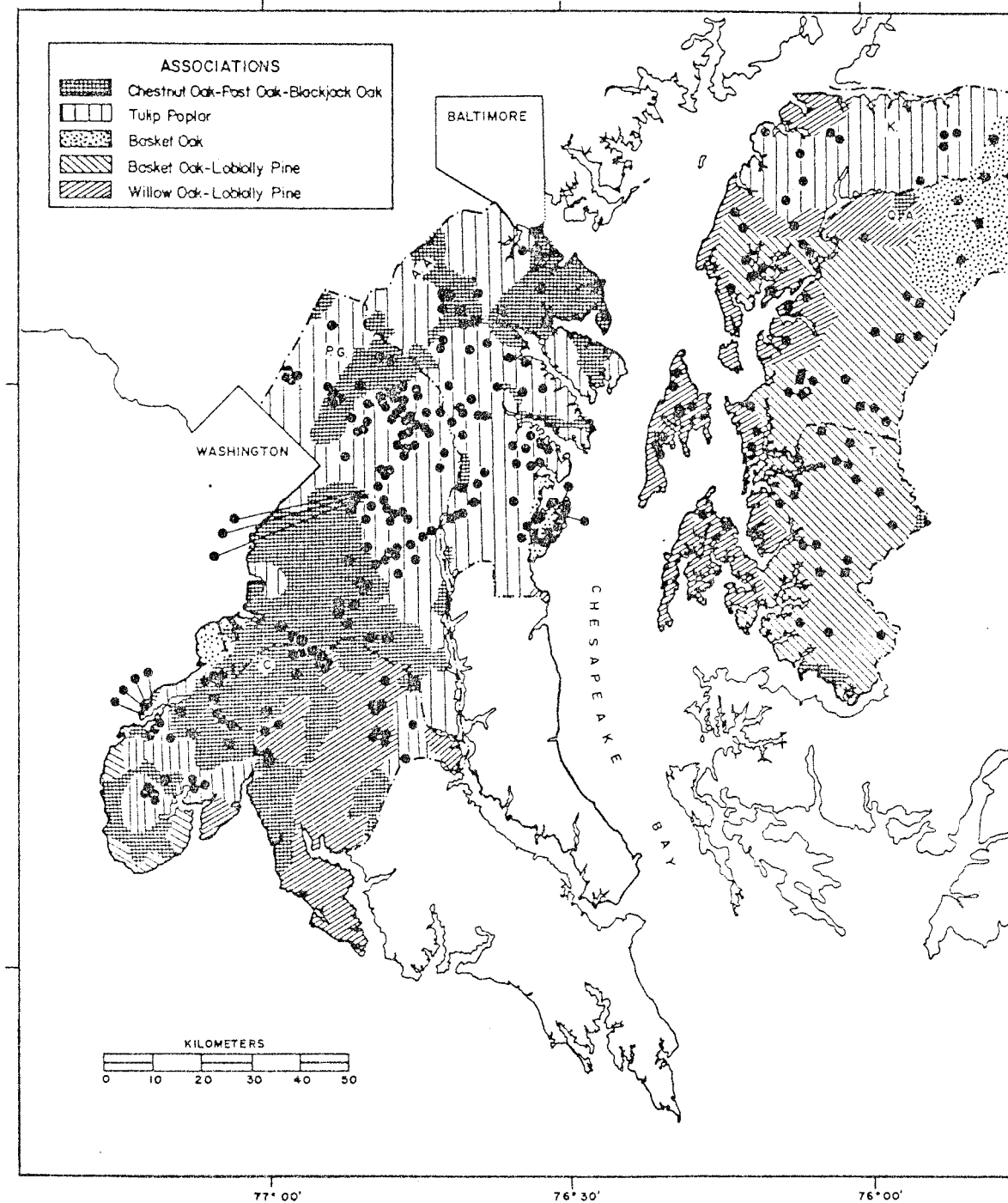


Figure 1. Map showing the six Maryland counties where field work was performed: Anne Arundel (A.A.), Prince Georges (P.G.), Charles (C), Kent (K), Queen Annes (Q.A.), and Talbot (T). Each black disc represents a forest patch that was studied. Dominant forest associations (Brush et al., 1980) are indicated by patterns as follows: Tulip Poplar - vertical lines; Chestnut Oak - Post Oak - Blackjack Oak - cross hatched; Basket Oak - Loblolly Pine - NW to SE diagonal hatching; Willow Oak - Loblolly Pine - NE - SW diagonal hatching; Basket Oak - gravel pattern.

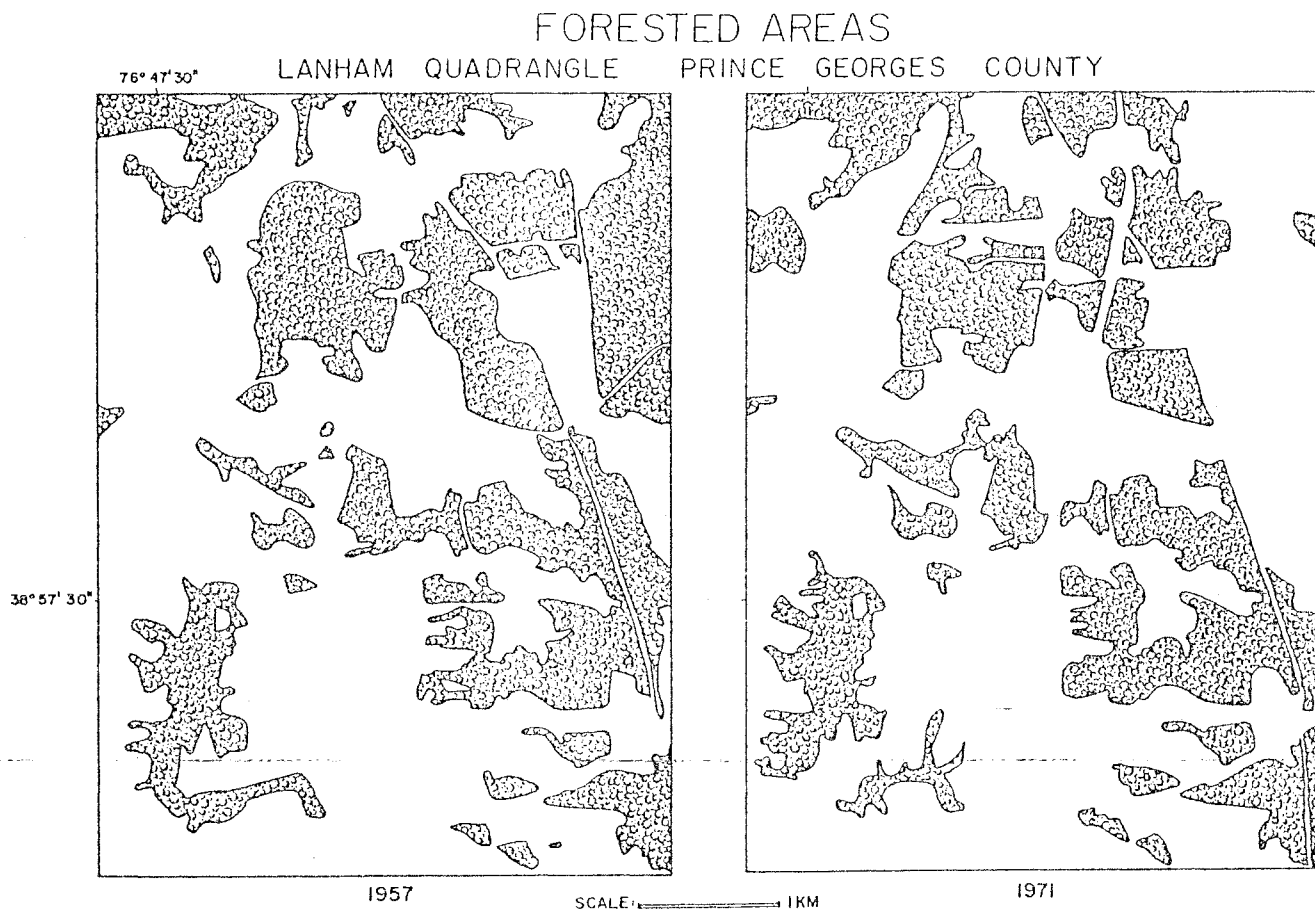


Figure 2. Recent changes in forest configuration, typical of suburbanizing sections of the three Western Shore counties. Forest was reduced by about 20% in total area, and was increasingly fragmented in the 14 year interval 1957 - 1971. Based on tracings from U.S.G.S. topographic maps.

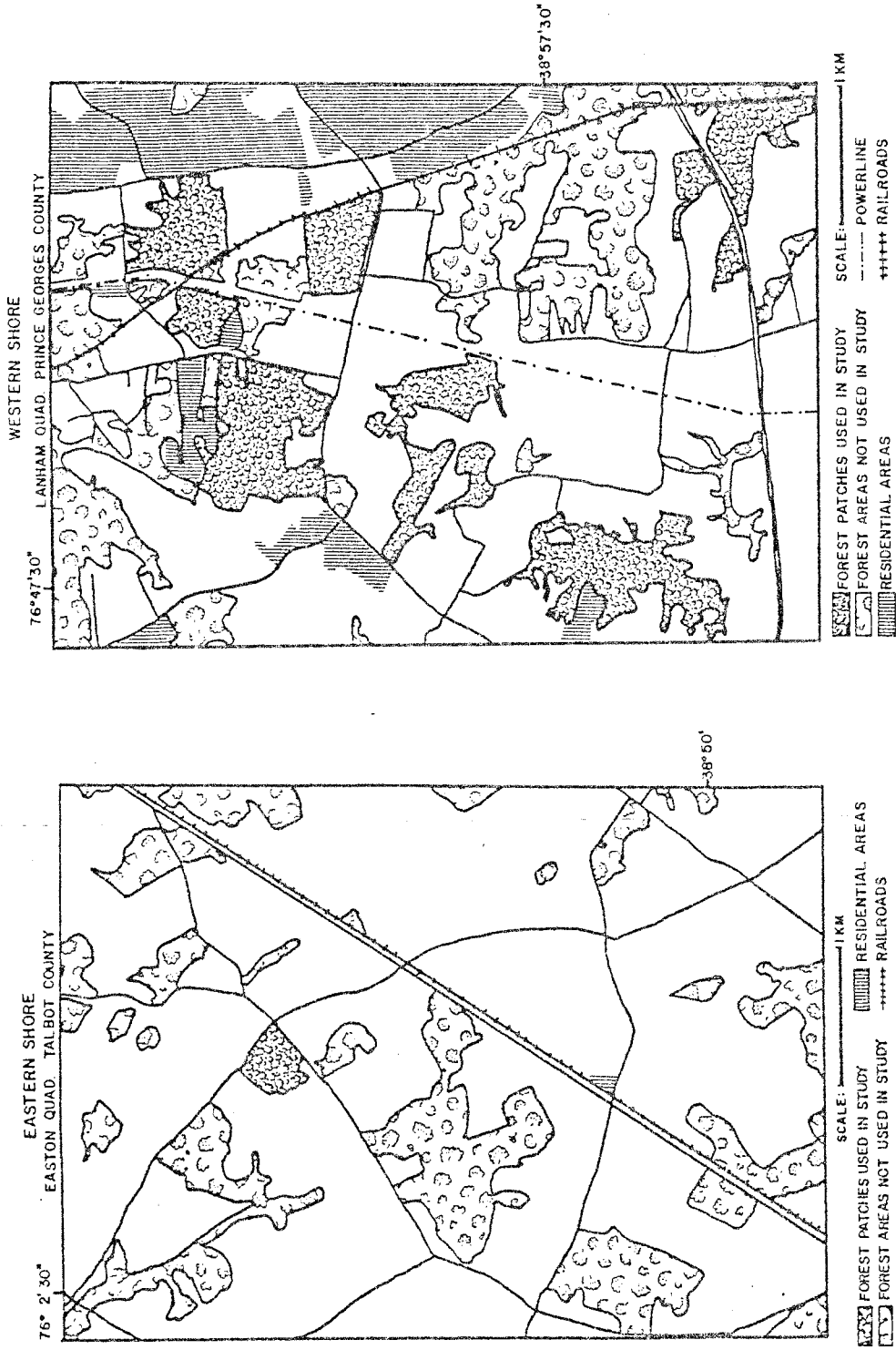


Figure 3. Typical pattern of land use and forest fragmentation in suburbanizing Western Shore county (left) and a more stable, rural Eastern Shore county (right).

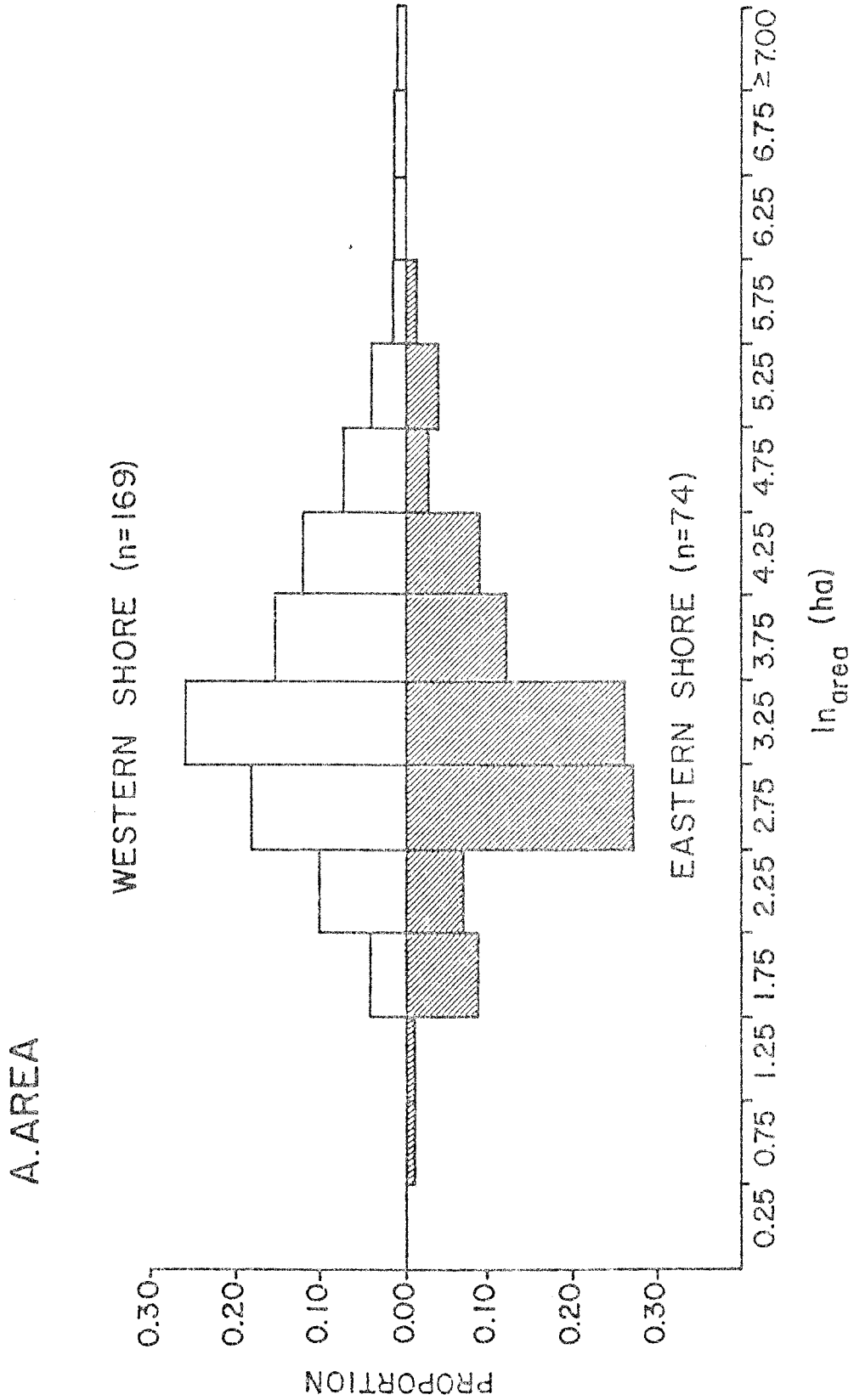


Figure 4a. Distribution of forest patch areas in Western vs Eastern Shore study areas.

B. ISOLATION

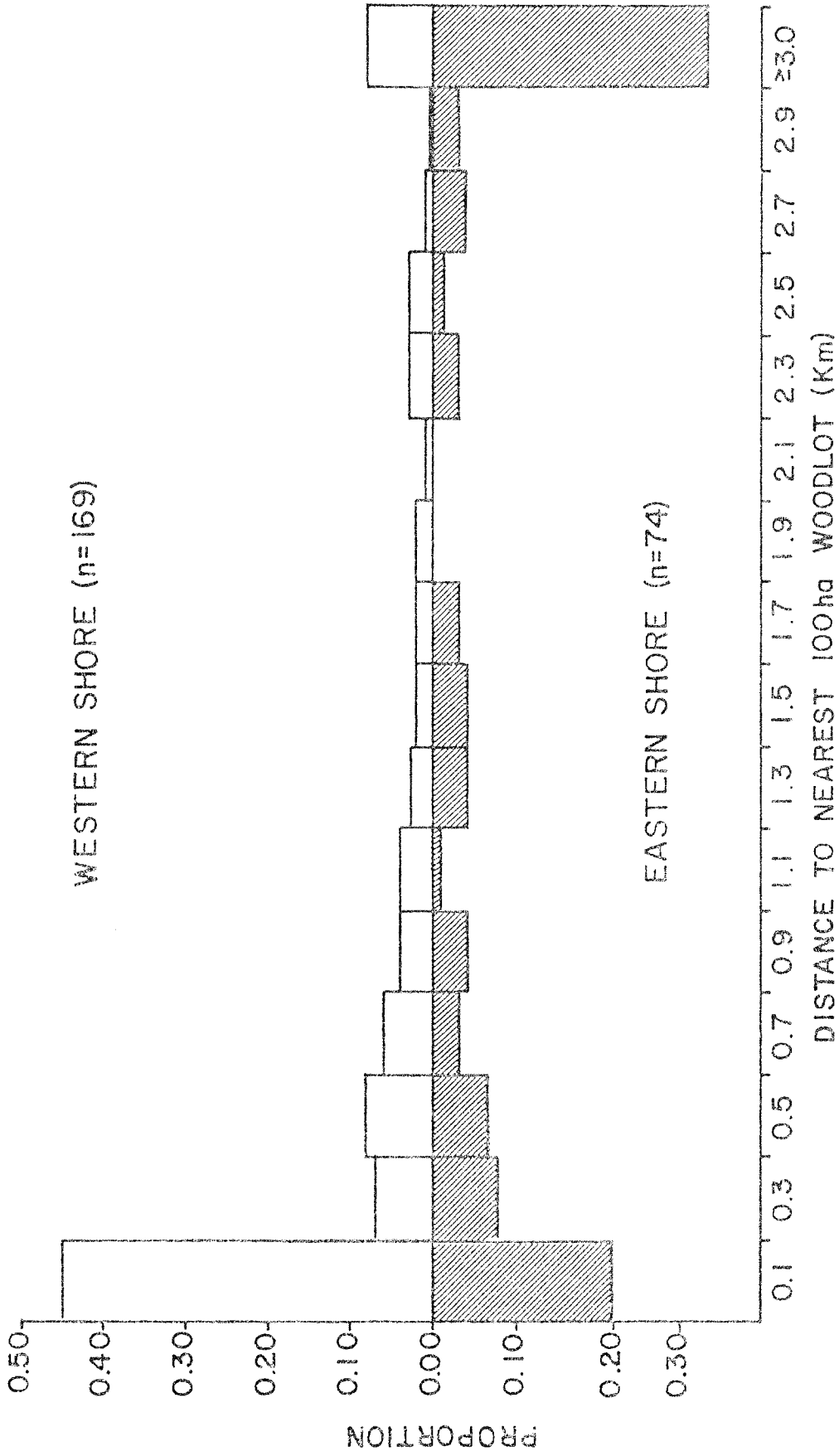


Figure 4b. Distribution of forest patch isolations in Western vs Eastern Shore study areas.

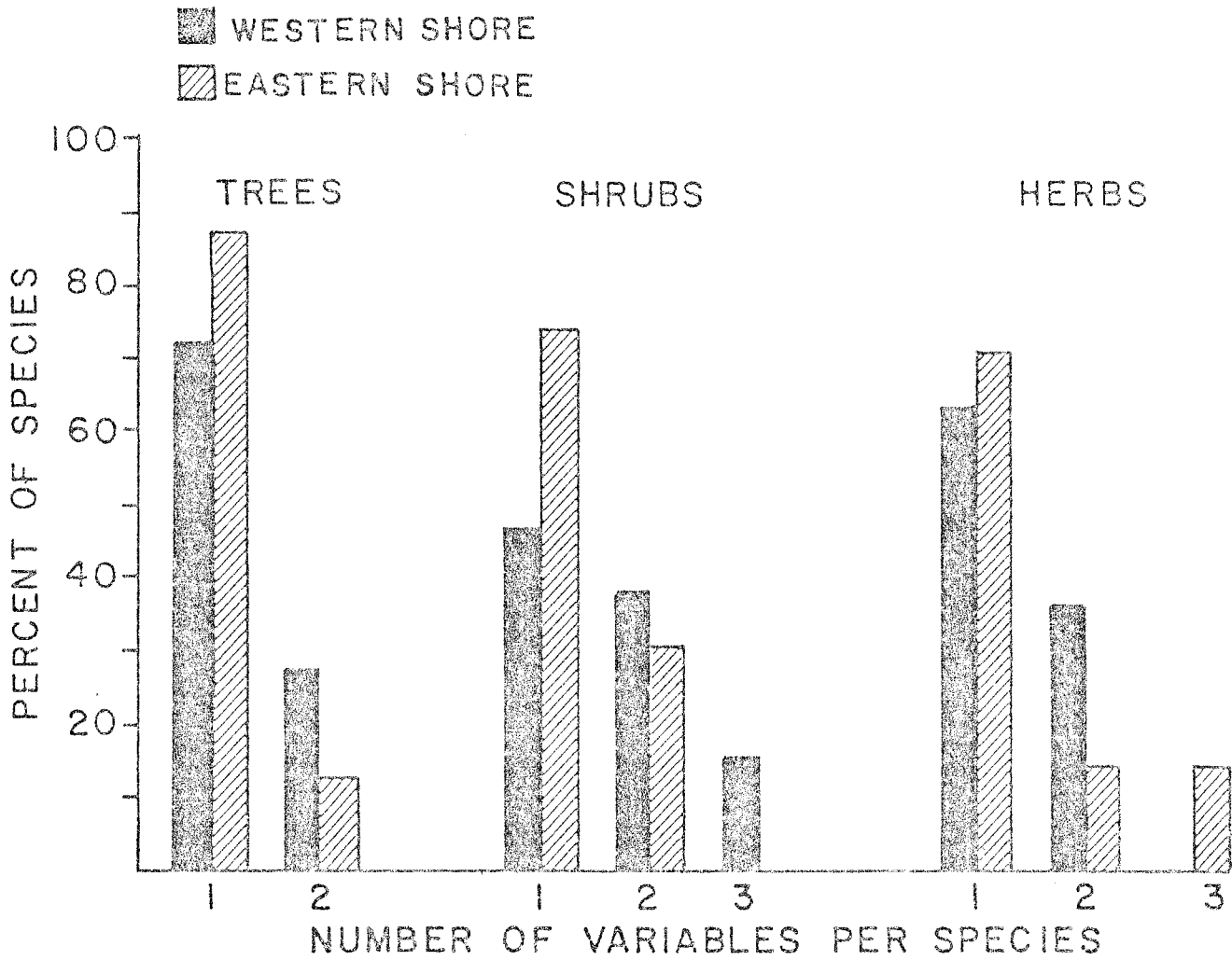


Figure 5. Histograms indicating percentage of trees, shrubs, and herbs that responded significantly to different numbers of predictor variables.-

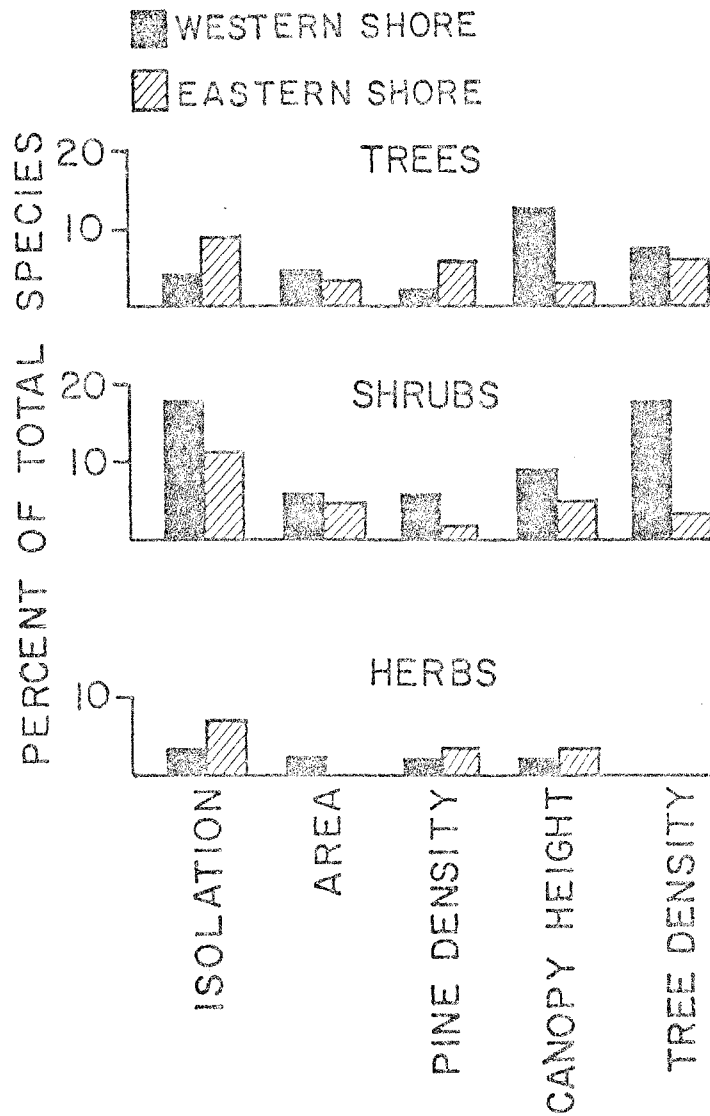


Figure 6. Percentage of the total number of species of trees, shrubs, and herbs that responded to isolation factors, patch area, pine density, canopy height, and tree density.

APPENDIX A

Description of abundance and cover classes used to sample herbaceous vegetation

I. Abundance

<u>Class</u>	<u>Estimated Density</u>
1	Plants scarce (1 - 4 individuals)
2	Plants infrequent (5 - 14 individuals)
3	Plants frequent (15 - 29 individuals)
4	Plants abundant (30 - 99 individuals)
5	Plants very abundant (over 100 individuals)

II. Cover

<u>Class</u>	<u>Estimated Percent of Plot Covered</u>
1	< 1
2	1 - 5
3	6 - 25
4	26 - 50
5	51 - 75
6	76 - 100

APPENDIX B

Procedures used to calculate dependent plant variables used in stepwise multiple regression of community variables.

1. Total plants species (TPS) for each forest:

$$\text{TPS} = \text{TTS} + \text{TSS} + \text{THS} \text{ where}$$

TTS = total number of tree species

TSS = total number of shrub species

THS = total number of herb species

2. Number of shrubs per hectare (NSD)

$$\text{NSD} = \sum_{i=1}^n \text{SD}_{\text{sp}_i} \text{ where SD is the shrub density of each species}$$

3. Average herb cover (HCT)

$$\text{HCT} = \sum_{i=1}^n \text{HC}_{\text{sp}_i} \text{ where HC is the herb cover of each species}$$

4. Density of pines (PIN) in each forest

$$\text{PIN} = \text{RTD of } \underline{\text{Pinus virginiana}} \text{ and } \underline{\text{P. taeda}}$$

5. Exponential diversity of trees (TDE)

$$\text{TDE} = e^{\text{TDS}} \text{ where TDS} = \text{Shannon - Weiner diversity (H')}.$$

$$H' = -\sum p \ln_e p. \text{ p} = \text{proportion of relative dominance of } \text{sp}_i$$

6. Exponential diversity of shrubs (SDE)

This is similar to TDE except that relative dominance values of shrubs were used to calculate H'

7. Exponential diversity of herbs (HDE)

This is similar to TDE except that relative dominance values of herbs were used to calculate H'

APPENDIX C

Procedures and formulas used in calculations for herbs, shrubs, and trees in forest patches.

HERBS

1. Average cover (HC) for each species

$$HC = \text{sum of cover class values } sp_i \div 20^*$$

*In forests with an area of more than 100 ha 40 quadrats were sampled.

2. Relative cover (RHC)

$$RHC_{sp_i} = \frac{HC_{sp_i}}{\sum_{i=1}^n HC_{sp_i}}$$

3. Average abundance (HA) for each species

$$HA = \text{sum of abundance class values for } sp_i \div 20^*$$

*This value was 40 for patches greater than 100 ha.

4. Relative abundance (RHA)

$$RHA = \frac{HA_{sp_i}}{\sum_{i=1}^n HA_{sp_i}} \quad (100)$$

5. Frequency (HF) for each species

$$HF_{sp_i} = (\text{number of plots with } sp_i) \div 20^*$$

*This value was 40 for patches greater than 100 Ha.

6. Relative frequency (RHF) for each species

$$RHF_{sp_i} = \frac{HF_{sp_i}}{\sum_{i=1}^n HF_{sp_i}} \quad (100)$$

7. Relative dominance (RDH) for each species

$$RDH_{sp_i} = RHC_{sp_i} + RHA_{sp_i} + RHF_{sp_i}$$

SHRUBS

1. Density (SD) for each species calculated as number of stems per hectare

$$SD_{sp_i} = (\sum \text{stems of } sp_i \text{ in plots 1 through 5}) A^*$$

*This conversion factor was 21.7 for patches on the Western Shore and 41.7 for the Eastern Shore.

2. Relative density (RSD) for each species

$$RSD_{sp_i} = \frac{SD_{sp_i}}{\sum_{i=1}^n SD_{sp_i}} (100)$$

3. Frequency (SF) for each species

$$SF_{sp_i} = (\text{number of plots with species}_i) \div 5$$

4. Relative frequency (RSF) for each species

$$RSF_{sp_i} = \frac{SF_{sp_i}}{\sum_{i=1}^n SF_{sp_i}} (100)$$

5. Relative dominance (RDS) for each species

$$RDS_{sp_i} = RSD_{sp_i} + RSF_{sp_i}$$

TREES

1. Density (DT) for each species

$$DT_{sp_i} = (\sum \text{number of stems of } sp_i \text{ in plots 1 through 5})$$

2. Relative density (RDT) for each species

$$RDT_{sp_i} = \frac{DT_{sp_i}}{FDT^*} (100)$$

***FDT = density of all trees in the forest = $\sum_{i=1}^n DT_{sp_i}$

3. Frequency (FT) for each species

$$FT_{sp_i} = (\text{number of plots with species}_i) \div 5$$

4. Relative frequency (RFT) for each species

$$\text{RFT} = \frac{\text{FT}_{\text{sp}_i}}{\sum_{i=1}^n \text{FT}_{\text{sp}_i}} \quad (100)$$

5. Basal area (BA) for each species

Diameter (DBH) measurements for each tree were converted to basal area (BA) equivalents with the following calculations

a. $\text{DBH} \div 2 = r$ (radius)

b. $\text{BA} = \pi r^2 = \text{BA in cm}$

c. $\text{BA} (10^{-4}) = \text{BA in m}^2$

d. $\text{BA}_{\text{sp}_i} = \sum_{j=1}^n \text{Ba of all individuals}_j \text{ of sp}_i$

e. $\text{BA}/\text{Ha} = \text{BA}_{\text{sp}_i} \quad (.5)$

6. Basal area of the forest (BAF)

$$\text{BAF} = \sum_{i=1}^n \text{BA all individual trees in forest}$$

7. Relative basal area (RBA) for each species

$$\text{RBA} = \frac{\text{BA}_{\text{sp}_i}}{\text{BAF}} \quad (100)$$

8. Relative dominance (RTD) for each species

$$\text{RTD}_{\text{sp}_i} = \text{RDT}_{\text{sp}_i} + \text{RFT}_{\text{sp}_i} + \text{RBA}_{\text{sp}_i}$$

APPENDIX D

1. Scientific names and associated acronyms for herbs sampled in 1978 and 1979

A. Non Poaceae, Cyperaceae and Juncaceae

<u>ACRONYM</u>	<u>SCIENTIFIC NAME</u>
ACMI	<i>Achillea millefolium</i> L.
ADPE	<i>Adiantum pedatum</i> L.
AGPA	<i>Agrimonia parviflora</i> Aiton.
AGPU	<i>Agrimonia pubescens</i> Wallroth.
ALSP	<i>Allium</i> sp. L.
AMAR	<i>Ambrosia artemisiifolia</i> L.
AMBR	<i>Amphicarpa bracteata</i> (L.) Fernald
ANPL	<i>Antennaria plantaginifolia</i> (L.) Richardson
ARTR	<i>Arisaema triphyllum</i> (L.) Schott
ASPL	<i>Asplenium platyneuron</i> (L.) Oakes
ASDI	<i>Aster divaricatus</i> L.
ASLA	<i>Aster lateriflorus</i> L. Britton
ASPU	<i>Aster puniceus</i> L.
ASSP	<i>Aster</i> sp. L.
ATAS	<i>Athyrium asplenioides</i> (Michaux) A.A. Eaton
BOCY	<i>Boehmeria cylindrica</i> (L.) Swartz
BODI	<i>Botrychium dissectum</i> Sprengel
BOVI	<i>Botrychium virginianum</i> (L.) Swartz
BOSP	<i>Botrychium</i> sp. Swartz
CARA	<i>Campsis radicans</i> (L.) Seemann
CACN	<i>Cardamine concatenata</i> (Michaux) Ahles
CESP	<i>Cerastium</i> sp. L.
CHMA	<i>Chimaphila maculata</i> (L.) Pursh
CHUM	<i>Chimaphila umbellata</i> (L.) Barton
CIAM	<i>Cimicifuga americana</i> Michaux
CIRA	<i>Cimicifuga racemosa</i> Nuttall
CILU	<i>Circaea lutetiana</i> spp. <i>canadensis</i> (L.) Ascherson & Magnus
CLVI	<i>Claytonia virginica</i> L.
COCA	<i>Collinsonia canadensis</i> L.
COCO	<i>Commelina communis</i> L.

A. Non Poaceae, Cyperaceae and Juncaceae (Continued)

<u>ACRONYM</u>	<u>SCIENTIFIC NAME</u>
CRR1	<i>Crataegus</i> sp. L.
CRCA	<i>Cryptotaenia canadensis</i> (L.) DC
CYVI	<i>Cynoglossum virginianum</i> L.
CYAC	<i>Cypripedium acaule</i> Aiton
DEPU	<i>Dennstaedtia punctilobula</i> (Michaux) Moore
DENU	<i>Desmodium nudiflorum</i> (L.) DC
DESP	<i>Desmodium</i> sp. Desvaux
DIVI	<i>Dioscorea villosa</i> L.
DRSP	<i>Dryopteris spinulosa</i> (Mueller) Watt
DUIN	<i>Duchesnea indica</i> (Andre.) Focke
EPVI	<i>Epifagus virginiana</i> (L.) Barton
ERHI	<i>Erechtites hieracifolia</i> (L.) Raf.
EUFI	<i>Eupatorium fistulosum</i> Barratt
EURE	<i>Eupatorium recurvans</i> Small
FASP	Fabaceae
GAAP	<i>Galium aparine</i> L.
GACI	<i>Galium circaezans</i> Michaux
GATR	<i>Galium triflorum</i> Michaux
GASE	<i>Galium</i> sp. L.
GEMA	<i>Geranium maculatum</i> L.
GECA	<i>Geum canadense</i> Jacquin
GLHE	<i>Glecoma hederacea</i> L.
GOPU	<i>Goodyera pubescens</i> (Willd.) R. Brown
HEHE	<i>Hedera helix</i> L.
HECA	<i>Helianthemum canadense</i> (L.) Michaux
HEFU	<i>Hemerocallis fluva</i> L.
HIVE	<i>Hieracium venosum</i> L.
HOCA	<i>Houstonia caerulea</i> L.
HOPU	<i>Houstonia purpurea</i> L.
HYST	<i>Hypericum stragalum</i> P. Adams and Robson.
HYSA	<i>Hypericum</i> sp. #1
HYSB	<i>Hypericum</i> sp. #2

A. Non Poaceae, Cyperaceae and Juncaceae (Continued)

<u>ACRONYM</u>	<u>SCIENTIFIC NAME</u>
IMCA	<i>Impatiens capensis</i> Meerb.
IPSP	<i>Ipomoea</i> sp. L.
LASP	<i>Lactuca</i> sp. L.
LASE	Lamiaceae
LOJA	<i>Lonicera japonica</i> Thunberg
LODI	<i>Lonicera dioica</i> L.
LYCI	<i>Lysimachia ciliata</i> L.
LYFL	<i>Lycopodium flabelliforme</i> (Fernald) Blanchard
LYLU	<i>Lycopodium lucidulum</i> Michaux
LYVI	<i>Lycopus virginicus</i> L.
MEVI	<i>Medeola virginiana</i> L.
MIRE	<i>Mitchella repens</i> L.
MOUN	<i>Monotropa uniflora</i> L.
ONSE	<i>Onoclea sensibilis</i> L.
ORSP	<i>Orchis spectabilis</i> L.
OSCL	<i>Osmorhiza claytonii</i> (Michaux) Clarke
OSLO	<i>Osmorhiza longistylis</i> (Torrey) DC.
OSCI	<i>Osmunda cinnamomea</i> L.
OSRE	<i>Osmunda regalis</i> var. <i>spectabilis</i> (Willd.) Gray
OXSP	<i>Oxalis</i> sp. L.
PAQU	<i>Parthenocissus quinquefolia</i> (L.) Planchon
PHLE	<i>Phyrma leptostachya</i> L.
PHAM	<i>Phytolacca americana</i> L.
PIPU	<i>Pilea pumila</i> (L.) Gray
POPE	<i>Podophyllum peltatum</i> L.
POBI	<i>Polygonatum biflorum</i> (Walter) Ell.
POAR	<i>Polygonum arifolium</i> L.
POCE	<i>Polygonum cespitosum</i> var. <i>longisetum</i> (DeBruyn) Stewart
POAC	<i>Polystichum acrostichoides</i> (Michaux) Schott
POCA	<i>Potentilla canadensis</i> L.
PTAQ	<i>Pteridium aquilinum</i> (L.) Kuhn
RAA	<i>Ranunculus abortivus</i> L.

A. Non Poaceae, Cyperaceae and Juncaceae (Continued)

<u>ACRONYM</u>	<u>SCIENTIFIC NAME</u>
RHRA	<i>Rhus radicans</i> L.
RUAR	<i>Rubus argutus</i> Link
RUAL	<i>Rubus allegheniensis</i> Porter
RUFL	<i>Rubus flagellaris</i> Willd.
RUHL	<i>Rubus hispidus</i> L.
RUOC	<i>Rubus occidentalis</i> L.
RUPH	<i>Rubus phoenicolasius</i> Maxim.
RUSP	<i>Rubus</i> sp. L.
RUCA	<i>Ruellia caroliniensis</i> (Walter) Steudel.
SACA	<i>Sanguinaria canadensis</i> L.
SACN	<i>Sanicula canadensis</i> L.
SASP	<i>Sanicula</i> sp. L.
SACE	<i>Saururus cernuus</i> L.
SCEL	<i>Scutellaria elliptica</i>
SCIN	<i>Scutellaria integrifolia</i> L. Muhl.
SISP	<i>Sisyrinchium</i> sp. L.
SMRA	<i>Smilacina racemosa</i> (L.) Desf.
SMGL	<i>Smilax glauca</i> Walter
SMRO	<i>Smilax rotundifolia</i> L.
SMSP	<i>Smilax</i> sp. L.
SOCA	<i>Solanum carolinense</i> L.
SOCE	<i>Solidago caesia</i> L.
SOJU	<i>Solidago juncea</i> Aiton.
SOOD	<i>Solidago odora</i> Aiton.
SORU	<i>Solidago rugosa</i> Miller
SOSA	<i>Solidago</i> sp. #1
SOSB	<i>Solidago</i> sp. #2
SOSP	<i>Solidago</i> sp. L.
SOAS	<i>Solidago</i> or <i>Aster</i> (vegetative)
STME	<i>Stellaria media</i> (L.) Cyrillo
SYFO	<i>Symplocarpos foetidus</i> (L.) Nuttall
THTH	<i>Thalictrum thalictroides</i> (L.) Boivin

A. Non Poaceae, Cyperaceae and Juncaceae (Continued)

<u>ACRONYM</u>	<u>SCIENTIFIC NAME</u>
THHE	<i>Thelypteris hexagonoptera</i> (Michaux) Weatherby
THNO	<i>Thelypteris noveboracensis</i> (L.) Nieuwland
THPA	<i>Thelypteris palustris</i> Schott
TIDI	<i>Tipularia discolor</i> (Pursh) Nuttall
TRSP	<i>Tradescantia</i> sp. L.
TOVI	<i>Tovara virginiana</i> (L.) Raf.
UVPE	<i>Uvularia perfoliata</i> L.
VEOF	<i>Veronica officinalis</i> L.
VITR	<i>Viola palmata</i> var. <i>triloba</i> (Schweirtz) Ging. ex DC.
WISE	<i>Viola</i> sp. L.
VIAE	<i>Vitis aestivalis</i> Michaux
VILA	<i>Vitis labrusca</i> L.
VISP	<i>Vitis</i> sp. L.
VIVU	<i>Vitis vulpina</i> L.

II. Scientific names and associated acronyms for herbs sampled in 1978 and 1979.

B. Poaceae, Cyperaceae and Juncaceae

<u>ACRONYM</u>	<u>SCIENTIFIC NAME</u>
AGHY	<i>Agrostis hyemalis</i> (Walter) BSP.
ANSC	<i>Andropogon scoparius</i> Michaux
CAAL	<i>Carex albolutescens</i> Schweinitz
CACE	<i>Carex cephalophora</i> Muhl. ex Sch Kuhr
CADI	<i>Carex digitalis</i> Willd.
CAGR	<i>Carex grisea</i> Wahlenberg
CALU	<i>Carex lurida</i> Wahlenberg
CARO	<i>Carex rosea</i> Sch Kuhr.
CASE	<i>Carex seorsa</i> Howe
CASW	<i>Carex swanii</i> (Fernald) Mackenzie
CASV	<i>Carex virescens</i> Muhl. ex Sch Kuhr
CASP	<i>Carex</i> sp. L.
CIAR	<i>Cinna arundinacea</i> L.
CYVE	Cyperaceae vegetative
DASP	<i>Danthonia spicata</i> (L.) Beauvois ex R. & S.
FEOB	<i>Festuca obtusa</i> Biehler
GLST	<i>Glyceria striata</i> (Lam.) Hitchcock
JUDI	<i>Juncus dichotomus</i> Ell.
JUEF	<i>Juncus effusus</i> L.
JUSP	<i>Juncus</i> sp. L.
LEVI	<i>Leersia virginica</i> Willd.
LUCA	<i>Luzula campestris</i> (L.) DC.
PABO	<i>Panicum boscii</i> Poiret.
PACL	<i>Panicum clandestinum</i> L.
PACO	<i>Panicum commutatum</i> Schultes.
PADI	<i>Panicum dichotomum</i> L.
PALA	<i>Panicum laxiflorum</i> Lam.
PASP	<i>Panicum spretum</i> Schultes
PAVE	<i>Panicum verrucosum</i> Muhl.
PASE	<i>Panicum</i> sp. L.
POAU	<i>Poa autumnalis</i> Muhl. ex Ell.

B. Poaceae, Cyperaceae and Juncaceae (Continued)

<u>ACRONYM</u>	<u>SCIENTIFIC NAME</u>
POPR	<i>Poa pratensis</i> L.
POVE	Poaceae vegetative
UNLA	<i>Uniola laxa</i> (L.) BSP.

III. Scientific names and associated acronyms for trees sampled in 1978 and 1979.

<u>ACRONYM</u>	<u>SCIENTIFIC NAME</u>
ACNE	<i>Acer negundo</i> L.
ACRU	<i>Acer rubrum</i> L.
AMSP	<i>Amelanchier canadensis</i> (L.) Medic.
BUNI	<i>Betula nigra</i> L.
CACA	<i>Carpinus caroliniana</i> Walter
CACO	<i>Carya cordiformis</i> (Wang.) K. Koch
CAGL	<i>Carya glabra</i> (Miller) Sweet
CAOV	<i>Carya ovalis</i> (Wang.) Sargent
CAOA	<i>Carya ovata</i> (Miller) K. Koch
CATO	<i>Carya tomentosa</i> (Poiret) Nuttall
CASC	<i>Carya</i> sp. Nuttall
CECA	<i>Cercis canadensis</i> L.
COFL	<i>Cornus florida</i> L.
DIVR	<i>Diospyros virginiana</i> L.
FAGR	<i>Fagus grandifolia</i> Ehrhart
FRAM	<i>Fraxinus americana</i> L.
FRFE	<i>Fraxinus pennsylvanica</i> Marshall
FRSP	<i>Fraxinus</i> sp. L.
ILOP	<i>Ilex opaca</i> Aiton
JUNI	<i>Juglans nigra</i> L.
JUVI	<i>Juniperus virginiana</i> L.
LIST	<i>Liquidambar styraciflua</i> L.
LITU	<i>Liriodendron tulipifera</i> L.
MORU	<i>Morus rubra</i> L.
MOSP	<i>Morus</i> L.
NYSY	<i>Nyssa sylvatica</i> Marshall
PATO	<i>Paulownia tomentosa</i> (Thunberg) Steudel
PIRI	<i>Pinus rigida</i> Miller
PITA	<i>Pinus taeda</i> L.
PIVI	<i>Pinus virginiana</i> Miller
PLOC	<i>Platanus occidentalis</i> L.
PODE	<i>Populus deltoides</i> Marshall

III. Scientific names and associated acronyms for trees sampled in 1978 and 1979.

<u>ACRONYM</u>	<u>SCIENTIFIC NAME</u>
POGR	<i>Populus grandidentata</i> Marshall
PRAV	<i>Prunus avium</i> L.
PRSE	<i>Prunus serotina</i> Ehrhart
QUAI	<i>Quercus alba</i> L.
QUCO	<i>Quercus coccinea</i> Muenchh.
QUFA	<i>Quercus falcata</i> Michaux
QUMA	<i>Quercus marilandica</i> Meunchh.
QUMI	<i>Quercus michauxii</i> Nuttall
QUPA	<i>Quercus palustris</i> Muenchh.
QUPH	<i>Quercus phellos</i> L.
QUPR	<i>Quercus prinus</i> L.
QURU	<i>Quercus rubra</i> L.
QUSP	<i>Quercus</i> sp. L.
QUST	<i>Quercus stellata</i> Wang.
QUVE	<i>Quercus velutina</i> Lam.
RHMA	<i>Rhododendron maximum</i> L.
ROPS	<i>Robinia psuedo-acacia</i> L.
SAAL	<i>Sassafras albidum</i> (Nuttall) Nees.
ULSP	<i>Ulmus</i> sp. L.

IV. Scientific names and associated acronyms for shrubs sampled in 1978 and 1979

<u>ACRONYM</u>	<u>SCIENTIFIC NAME</u>
ACNE	<i>Acer negundo</i> L.
ACRU	<i>Acer rubrum</i> L.
AIAL	<i>Ailanthus altissima</i> (Miller) Swingle.
ALSE	<i>Alnus</i> sp. Ehrhart (probably <i>A. serrulata</i> (Aiton) Willd.)
AMSP	<i>Amelanchier canadensis</i> (L.) Medic.
ARSP	<i>Aralia spinosa</i> L.
ASTR	<i>Asimina triloba</i> (L.) Dunal.
BETH	<i>Berberis thunbergii</i> DC.
BENI	<i>Betula nigra</i> L.
CAAM	<i>Callicarpa americana</i> L.
CACA	<i>Carpinus caroliniana</i> Walter
CACO	<i>Carya cardiformis</i> (Wang.) K. Koch
CAGL	<i>Carya ovalis</i> (Wang.) Sargent
CAOA	<i>Carya ovata</i> (Miller) K. Koch
CASC	<i>Carya</i> sp. Nuttall (Seedlings)
CATO	<i>Carya tomentosa</i> (Poiret) Nuttall
CADE	<i>Castanea dentata</i> (Marshall) Borkh.
CAPU	<i>Castanea pumila</i> (L.) Miller
CASS	<i>Catalpa</i> sp. L.
CEOC	<i>Celtis occidentalis</i> L.
CECA	<i>Cercis canadensis</i> L.
CESC	<i>Celastrus scandens</i> L.
CHVI	<i>Chioanthus virginicus</i> L.
CLAL	<i>Clethra alnifolia</i> L.
COFL	<i>Cornus florida</i> L.
COST	<i>Cornus stricta</i> Lam.
COAM	<i>Corylus americana</i> Walter
CRSP	<i>Crataegus</i> sp. L.
DIVR	<i>Diospyros virginiana</i> L.
EUAM	<i>Euonymus americanus</i> L.
FASP	Fabaceae
FAGR	<i>Fagus grandifolia</i> Ehrhart

IV. Scientific names and associated acronyms for shrubs sampled in 1978 & 1979. (Continued)

<u>ACRONYM</u>	<u>SCIENTIFIC NAME</u>
FRAM	<i>Fraxinus americana</i> L.
FRPE	<i>Fraxinus pennsylvanica</i> Marshall
FRSP	<i>Fraxinus</i> sp. L.
GABA	<i>Gaylussacia baccata</i> (Wang.) K. Koch
GAFR	<i>Gaylussacia frondosa</i> (L.) T. & G.
GASP	<i>Gaylussacia</i> HBK.
HAVI	<i>Hamamelis virginiana</i> L.
HYAR	<i>Hydrangea arborescens</i> L.
ILOP	<i>Ilex opaca</i> Aiton
ILLA	<i>Ilex laevigata</i> (Pursh) Gray
ILVE	<i>Ilex verticillata</i> (L.) Gray
ITVI	<i>Itea virginica</i> L.
JUNI	<i>Juglans nigra</i> L.
JUVI	<i>Juniperus virginiana</i> L.
KALA	<i>Kalmia latifolia</i> L.
LERA	<i>Leucothoe racemosa</i> (L.) Gray
LISP	<i>Ligustrum</i> sp. L.
LIVU	<i>Ligustrum vulgare</i>
LIOB	<i>Ligustrum obtusifolium</i>
LIBE	<i>Lindera benzoin</i> (L.) Blume
LIST	<i>Liquidambar styraciflua</i> L.
LITU	<i>Liriodendron tulipifera</i> L.
LYLI	<i>Lyonia ligustrina</i> (L.) DC.
MAVI	<i>Magnolia virginiana</i> L.
MOAL	<i>Morus alba</i> L.
MORU	<i>Morus rubra</i> L.
MOSP	<i>Morus</i> sp. L.
MYCE	<i>Myrica cerifera</i> L.
MYPE	<i>Myrica pennsylvanica</i> Loisel.
NYSY	<i>Nyssa sylvatica</i> Marshall
PATO	<i>Paulownia tomentosa</i> (Thunberg) Steudel
PLOC	<i>Platanus occidentalis</i> L.

IV. Scientific names and associated acronyms for shrubs sampled in 1978 & 1979. (Continued)

<u>ACRONYM</u>	<u>SCIENTIFIC NAME</u>
PIRI	<i>Pinus rigida</i> Miller
PITA	<i>Pinus taeda</i> L.
PISP	<i>Pinus</i> sp. L.
PIVI	<i>Pinus virginiana</i> Miller
PODE	<i>Populus deltoides</i> Marshall
POGR	<i>Populus grandidentata</i> Michaux
POHE	<i>Populus heterophylla</i> L.
POSP	<i>Populus</i> sp. L.
PRAV	<i>Prunus avium</i> L.
PRPE	<i>Prunus pennsylvanica</i> L.
PRSE	<i>Prunus serotina</i> Ehrhart
PYAR	<i>Sorbus arbutifolia</i> L. Heynold var. <i>arbutifolia</i>
QUAL	<i>Quercus alba</i> L.
QUFA	<i>Quercus falcata</i> Michaux
QUIL	<i>Quercus ilicifolia</i> Wang.
QUMA	<i>Quercus marilandica</i> Muenchh.
QUMI	<i>Quercus michauxii</i> Nuttall
QUPA	<i>Quercus palustris</i> Muenchh.
QUPH	<i>Quercus phellos</i> L.
QUPR	<i>Quercus prinus</i> L.
QUPI	<i>Quercus prinoides</i> Willd.
QURU	<i>Quercus rubra</i> L.
QUSP	<i>Quercus</i> sp. L.
QUST	<i>Quercus stellata</i> Wang.
QUVE	<i>Quercus velutina</i> Lam.
RHAT	<i>Rhododendron atlanticum</i> (Ash.) Rehder
RHMA	<i>Rhododendron maximum</i> L.
RHNU	<i>Rhododendron nudiflorum</i> (L.) Torrey
RHVI	<i>Rhododendron viscosum</i> (L.) Torrey
RHSP	<i>Rhododendron</i> sp. L.
RHCO	<i>Rhus copallina</i> L.
RHTY	<i>Rhus typhina</i> L.

IV. Scientific names and associated acronyms for shrubs sampled in 1978 & 1979. (Continued)

<u>ACRONYM</u>	<u>SCIENTIFIC NAME</u>
ROPS	<i>Robinia psuedo-acacia</i> L.
ROCA	<i>Rosa carolina</i> L.
ROMU	<i>Rosa multiflora</i> Thunberg
ROPA	<i>Rosa palustris</i> Marshall
SACD	<i>Sambucus canadensis</i> L.
SAPU	<i>Sambucus pubens</i> Michaux
SAAL	<i>Sassafras albidum</i> (Nuttall) Nees.
TIAM	<i>Tilia americana</i> L.
ULAM	<i>Ulmus americana</i> L.
ULRU	<i>Ulmus rubra</i> Muhl.
ULSP	<i>Ulmus</i> sp. L.
VAAT	<i>Vaccinium atrococcum</i> (Gray) Porter
VACO	<i>Vaccinium corymbosum</i> L.
VAST	<i>Vaccinium stamineum</i> L.
VAVA	<i>Vaccinium vacillans</i> Torrey
VASP	<i>Vaccinium</i> sp. L.
VIAC	<i>Vibernum acerfolium</i> L.
VIDE	<i>Vibernum dentatum</i> L.
VINU	<i>Vibernum nudum</i> L.
VIPR	<i>Vibernum prunifolium</i> L.
VISP	<i>Vibernum</i> sp. L.
WISI	<i>Wisteria sinensis</i> (Sims) Sweet

APPENDIX E

Common names, scientific names, and acronyms for 31 most abundant birds that bred in upland forest-interior habitat within the eastern Maryland study area. Hawks, owls, and caprimulgids were not considered, due to difficulties in detection or very large home ranges, or both.

<u>COMMON NAME</u>	<u>SCIENTIFIC NAME</u>	<u>ACRONYM</u>
Acadian Flycatcher	(<u>Empidonax virescens</u>)	ACFL
Black-and-white Warbler	(<u>Mniotilta varia</u>)	BAWW
Blue-gray Gnatcatcher	(<u>Polioptila caerulea</u>)	BGGN
Blue Jay	(<u>Cyanocitta cristata</u>)	BLJA
Cardinal	(<u>Cardinalis cardinalis</u>)	CARD
Carolina Chickadee	(<u>Parus carolinensis</u>)	CACH
Carolina Wren	(<u>Thryothorus ludovicianus</u>)	CAWR
Common Flicker	(<u>Colaptes auratus</u>)	COFL
Downy Woodpecker	(<u>Picoides pubescens</u>)	DOWO
Eastern Wood Pewee	(<u>Contopus virens</u>)	EWPE
Gray Catbird	(<u>Dumetella carolinensis</u>)	GRCA
Great Crested Flycatcher	(<u>Myiarchus crinitus</u>)	GCFL
Hairy Woodpecker	(<u>Picoides villosus</u>)	HAWO
Hooded Warbler	(<u>Wilsonia citrina</u>)	HOWA
Kentucky Warbler	(<u>Oporornis formosus</u>)	KEWA
Northern Parula Warbler	(<u>Parula americana</u>)	NOPA
Ovenbird	(<u>Seiurus aurocapillus</u>)	OVEN
Pileated Woodpecker	(<u>Dryocopus pileatus</u>)	PIWO
Pine Warbler	(<u>Dendroica pinus</u>)	PIWA
Red-bellied Woodpecker	(<u>Melanerpes carolinus</u>)	RBWO
Red-eyed Vireo	(<u>Vireo olivaceus</u>)	REVI
Ruby-throated Hummingbird	(<u>Archilochus colubris</u>)	RTHU
Rufous-sided Towhee	(<u>Pipilo erythrophthalmus</u>)	RSTO
Scarlet Tanager	(<u>Piranga olivacea</u>)	SCTA
Tufted Titmouse	(<u>Parus bicolor</u>)	TUTI
White-breasted Nuthatch	(<u>Sitta carolinensis</u>)	WBNU
White-eyed Vireo	(<u>Vireo griseus</u>)	WEVI
Wood Thrush	(<u>Hylocichla mustelina</u>)	WOTH
Worm-eating Warbler	(<u>Helmitheros vermivorus</u>)	WEWA
Yellow-billed Cuckoo	(<u>Coccyzus americanus</u>)	YBCU
Yellow-throated Vireo	(<u>Vireo flavifrons</u>)	YTVI

Appendix F. Multiple regression equations for bird community properties and individual bird species abundances in 74 tracts on the Eastern Shore and Ill tracts on the Western Shore. Predictor variables with significant F-values ($P < .05$) are listed in order of decreasing significance levels. Acronyms for predictor variables are defined in the text. Numbers in parentheses are the number of forest patches in which a given species occurred.

Dependent Variables	Best Regression Equation	P > F
A. Community Variables		
1. Total Number of Bird Species (NSB)		
a. Eastern Shore	: NSB = 29.00 - 1.48 LAR - .10 CHT - .22 HCT	.0001
b. Western Shore	: NSB = 19.80 - .10 PIN - .12 ISB	.0091
c. Both shores	: NSB = 22.45 - .73 LAR	.0027
2. Total Number of Pairs of Birds (NPR)		
a. Eastern Shore	: NPR = 18.82 - .83 LAR	.0062
b. Western Shore	: NPR = 19.07 - .10 ISA + .25 HCT - .0001 NSD	.0002
c. Both shores	: NPR = 16.31 + 23 HCT - .05 ISA + .07 BAF - .53 LAR	.0001
3. Exponential Diversity of Bird Species (BDE)		
a. Eastern Shore	: No significant regression	ns
b. Western Shore	: BDE = 12.41 - .003 FDT	.0073
c. Both Shores	: BDE = 12.24 - .002 FDT	.0131
4. Number of Forest-interior Bird Species (FSP)		
a. Eastern Shore	: No significant regression	ns
b. Western Shore	: FSP = 13.92 + .17 HDE - .07 ISA	.0041
c. Both shores	: FSP = 14.38 + .09 HDE + .35 LAR - .002 FDT	.0006
5. Number of Pairs of Forest-interior Bird Species (FPR)		
a. Eastern Shore	: FPR = 11.02 - .42 ISA + .07 BAF	.0295
b. Western Shore	: FPR = 10.67 + .29 HCT - .10 ISA + .12 BAF	.0001
c. Both shores	: FPR = 7.89 + .10 BAF - .06 ISA + .07 TPS + .18 HCT	.0001

Appendix F. (Continued)

Dependent Variables	Best Regression Equation	P > F
6. Number of "Edge" Bird Species (ESP)		
a. Eastern Shore	: ESP = 14.59 - 1.68 LAR - .25 HCT - .08 CHT	.0001
b. Western Shore	: ESP = 7.99 - .63 LAR - .06 CHT	.0005
c. Both shores	: ESP = 12.48 - 1.02 LAR - .06 TPS - .06 CHT	.0001
7. Number of Pairs of "Edge" Bird Species (EPR)		
a. Eastern Shore	: EPR = 9.74 - 1.30 LAR - .06 TPS	.0001
b. Western Shore	: EPR = 7.32 - .63 LAR - .03 PCC - .03 BAF	.0001
c. Both shores	: EPR = 7.43 - .82 LAR - .04 TPS	.0001
B. Species Abundances		
1. Acadian Flycatcher (ACFL)		
a. Eastern Shore (n = 16)	: ACFL = .02 HCT	.0020
b. Western Shore (n = 85)	: ACFL = .60 + .03 TPS - .02 ISC - .17 LAR	.0001
c. Both shores (n = 101)	: ACFL = -.43 + .04 TPS - .02 ISC	.0001
2. Black-and-white Warbler (BAWW)		
a. Eastern Shore (n = 4)	: No significant regression	ns
b. Western Shore (n = 12)	: BAWW = .26 - .01 BAF	.0006
c. Both shores (n = 16)	: BAWW = .13 - .004 BAF - .001 ISC + .02 LAR	.0001
3. Blue-gray Gnatcatcher (BGGN)		
a. Eastern Shore (n = 11)	: BGGN = .04 - .001 ISB	.0315
b. Western Shore (n = 15)	: BGGN = .29 - .003 PCC - .002 ISC	.0032
c. Both shores (n = 26)	: BGGN = .19 - .002 PCC - .002 ISB	.0002
4. Blue Jay (BLJA)		
a. Eastern Shore (n = 70)	: BLJA = .88 - .05 HCT	.0008
b. Western Shore (n = 86)	: BLJA = .60 + .01 ISC - .01 TPS	.0002
c. Both shores (n = 156)	: BLJA = .52 - .01 TPS + .006 ISC + .0001 NSD + .01 CHT	.0001

Appendix F. (Continued)

Dependent Variables	Best Regression Equation	P > F
5. Cardinal (CARD)		
a. Eastern Shore (n = 72)	: CARD = .70 + .08 HCT + .13 ISB	.0001
b. Western Shore (n = 106)	: CARD = 1.55 + .07 HCT - .0001 NSD	.0001
c. Both shores (n = 178)	: CARD = 1.31 + .07 HCT - .0001 NSD	.0001
6. Carolina Chickadee (CACH)		
a. Eastern Shore (n = 61)	: CACH = 1.23 - .010 ISB - .01 TPS	.0168
b. Western Shore (n = 98)	: CACH = .40 + .01 ISC	.0050
c. Both shores (n = 159)	: CACH = .86 - .02 SDE	.0009
7. Carolina Wren (CAWR)		
a. Eastern Shore (n = 29)	: CAWR = .11 + .01 ISA	.0375
b. Western Shore (n = 46)	: CAWR = .62 - .01 SDE - .05 LAR	.0062
c. Both shores (n = 75)	: CAWR = .12 + .006 ISA	.0015
8. Common Flicker (COFL)		
a. Eastern Shore (n = 65)	: No significant regression	ns
b. Western Shore (n = 41)	: COFL = .06 + .003 ISC	.0077
c. Both shores (n = 106)	: COFL = .42 + .005 ISC - .006 TPS	.0001
9. Downy Woodpecker (DOWO)		
a. Eastern Shore (n = 52)	: DOWO = .58 + .0003 PIN - .01 ISC - .07 LAR	.0001
b. Western Shore (n = 82)	: DOWO = .03 + .005 ISA + .01 CHT	.0008
c. Both shores (n = 134)	: DOWO = .25 - .04 LAR + .01 CHT	.0038
10. Eastern Wood Pewee (EWPE)		
a. Eastern Shore (n = 57)	: EWPE = 1.78 - .01 PIN - .09 TDE - .001 NSD	.0007
b. Western Shore (n = 71)	: EWPE = -.16 + .03 CHT	.0043
c. Both shores (n = 128)	: EWPE = .42 + .02 CHT - .09 LAR	.0026

Appendix F. (Continued)

Dependent Variables	Best Regression Equation	P > F
11. Gray Catbird (GRCA)		
a. Eastern Shore (n = 16)	: GRCA = .60 - .14 LAR	.0001
b. Western Shore (n = 24)	: GRCA = .19 - .04 LAR	.0324
c. Both shores (n = 40)	: GRCA = .52 - .08 LAR - .02 TDE	.0001
12. Great Crested Flycatcher (GCFL)		
a. Eastern Shore (n = 64)	: GCFL = - .24 + .01 BAF + .02 SDE	.0033
b. Western Shore (n = 38)	: GCFL = .13 - .01 HCT	.0302
c. Both shores (n = 102)	: GCFL = .15 + .006 ISC - .02 HCT + .002 PIN	.0001
13. Hairy Woodpecker (HAWO)		
a. Eastern Shore (n = 24)	: HAWO = .05 + .002 ISB	.0300
b. Western Shore (n = 20)	: No significant regression	ns
c. Both shores (n = 44)	: HAWO = .04 + .002 ISB	.0006
14. Hooded Warbler (HOWA)		
a. Eastern Shore (n = 2)	: No significant regression	ns
b. Western Shore (n = 50)	: HOWA = .31 + .12 LAR - .001 FDT	.0039
c. Both shores (n = 52)	: HOWA = - .08 + .01 TPS + .08 LAR - .004 ISC + .0004 FDT	.0001
15. Kentucky Warbler (KEWA)		
a. Eastern Shore (n = 29)	: KEWA = - .26 + .18 LAR - .01 PIN	.0001
b. Western Shore (n = 45)	: KEWA = - .27 + .04 HCT + .06 LAR	.0001
c. Both shores (n = 74)	: KEWA = - .24 + .03 HCT + .09 LAR	.0001
16. Northern Parula Warbler (NOPA)		
a. Eastern Shore (n = 3)	: No significant regression	ns
b. Western Shore (n = 23)	: NOPA = - .81 + .01 TPS + .08 LAR	.0001
c. Both shores (n = 26)	: NOPA = - .58 + .01 TPS + .06 LAR	.0001

Appendix F. (Continued)

Dependent Variables	Best Regression Equation	P > F
17. Ovenbird (OVEN)		
a. Eastern Shore (n = 29)	: OVEN = - 1.17 + .002 FDT + .18 LAR	.0013
b. Western Shore (n = 79)	: OVEN = - 1.25 - .04 ISA + .002 FDT + .02 PCC .06 SDE - .08 TDE	.0001
c. Both shores (n = 108)	: OVEN = - .91 - .02 ISA + .002 FDT + .05 SDE + .04 HCT	.0001
18. Pileated Woodpecker (PIWO)		
a. Eastern Shore (n = 6)	: PIWO = -.06 + .02 LAR	.0327
b. Western Shore (n = 11)	: PIWO = .04 - .001 ISC	.0480
c. Both shores (n = 17)	: No significant regression	ns
19. Pine Warbler (PIWA)		
a. Eastern Shore (n = 23)	: PIWA = - .33 + .01 PIN + .01 BAF	.0001
b. Western Shore (n = 15)	: PIWA = .38 + .02 PIN - .005 PCC	.0001
c. Both shores (n = 38)	: PIWA = .34 + .01 PIN - .004 PCC	.0001
20. Red-bellied Woodpecker (RBWO)		
a. Eastern Shore (n = 71)	: RBWO = .77 - .03 HDE - .002 PIN	.0023
b. Western Shore (n = 83)	: RBWO = - .17 + .02 CHT - .01 PIN	.0001
c. Both shores (n = 154)	: RBWO = .40 + .02 BAF - .0001 FDT	.0001
21. Red-eyed Vireo (REVI)		
a. Eastern Shore (n = 63)	: REVI = .79 + .09 HDE	.0046
b. Western Shore (n = 109)	: REVI = - .17 + .02 CHT - .01 PIN	.0001
c. Both shores (n = 172)	: REVI = - .005 + .04 TPS - .01 PIN - .02 ISC + .23 LAR - .0001 NSD + .02 BAF	.0001
22. Ruby-throated Hummingbird (RTHU)		
a. Eastern Shore (n = 0)	: No occurrences	-
b. Western Shore (n = 10)	: No significant regression	ns
c. Both shores (n = 10)	: RTHU = - .02 + .002 SDE	.0247

Appendix F. (Continued)

Dependent Variables	Best Regression Equation	P > F
23. Rufous-sided Towhee (RSTO)		
a. Eastern Shore (n = 46)	: RSTO = 1.06 - .08 TDE	.0392
b. Western Shore (n = 70)	: RSTO = - .11 + .01 ISC + .001 FDT	.0001
c. Both shores (n = 116)	: RSTO = .47 + .001 FDT - .04 TDE	.0021
24. Scarlet Tanager (SCTA)		
a. Eastern Shore (n = 54)	: SCTA = - .22 + .04 SDE	.0001
b. Western Shore (n = 101)	: No significant regression	ns
c. Both shores (n = 155)	: SCTA = .16 + .03 SDE - .004 PIN	.0001
25. Tufted Titmouse (TUTI)		
a. Eastern Shore (n = 73)	: No significant regression	ns
b. Western Shore (n = 108)	: No significant regression	ns
c. Both shores (n = 181)	: TUTI = 1.50 - .005 PCC	.0434
26. White-breasted Nuthatch (WBNU)		
a. Eastern Shore (n = 4)	: WBNU = .03 - .001 ISA	.0435
b. Western Shore (n = 10)	: WBNU = .04 + .01 CHT - .002 TPS	.0004
c. Both shores (n = 14)	: WBNU = - .06 + .003 CHT	.0009
27. White-eyed Vireo (WEVI)		
a. Eastern Shore (n = 15)	: WEVI = .14 - .002 PIN	.0215
b. Western Shore (n = 19)	: WEVI = - .04 + .02 HCT + .06 LAR - .01 BAF	.0012
c. Both shores (n = 34)	: WEVI = .20 + .20 HCT - .005 BAF	.0012
28. Worm-eating Warbler (WEWA)		
a. Eastern Shore (n = 9)	: WEWA = - .19 + .01 BAF - .003 ISC	.0041
b. Western Shore (n = 6)	: WEWA = .10 - .002 TPS	.0475
c. Both shores (n = 15)	: WEWA = .03 + .003 PIN - .003 ISB	.0001

Appendix F. (Continued)

Dependent Variables	Best Regression Equation	P > F
29. Wood Thrush (WOTH)		
a. Eastern Shore (n = 72)	: WOTH = $-.05 + .04 \text{ TPS} - .1802 \text{ ISB} + .04 \text{ CHT}$.0001
b. Western Shore (n = 108)	: WOTH = $.22 - .023 \text{ ISB} + .04 \text{ CHT} + .01 \text{ ISC}$.0001
c. Both shores (n = 180)	: WOTH = $.22 - .02 \text{ ISB} + .04 \text{ CHT} + .01 \text{ ISC} + .02 \text{ BAF}$.0001
30. Yellow-billed Cuckoo (YBCU)		
a. Eastern Shore (72)	: YBCU = $.70 - .01 \text{ ISA} + .11 \text{ LAR}$.0059
b. Western Shore (n = 72)	: YBCU = $.06 + .07 \text{ LAR}$.0324
c. Both shores (n = 144)	: YBCU = $1.04 - .01 \text{ TPS} + .01 \text{ ISA} - .01 \text{ ISC}$.0001
31. Yellow-throated Vireo (YTVI)		
a. Eastern Shore (n = 1)	: No significant regression	ns
b. Western Shore (n = 10)	: YTVI = $-.16 + .01 \text{ SDE}$.0190
c. Both shores (n = 11)	: YTVI = $-.05 + .01 \text{ SDE} - .002 \text{ ISA}$.0005