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PLOT SIZE AS A FACTOR IN WINTER BIRD-POPULATION STUDIES

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ABSTRACT.—The influence of plot size on the results of a Winter Bird-Population Study was explored by dividing a 58.3-ha (144-acre) area of apparently homogeneous mature pine habitat into nine 6.5-ha subplots. Bird density and species richness were estimated for the nine subplots. To simulate progressively larger sample areas, all possible combinations of the subplot survey results were made. Variation in estimates of the density and species richness in the 6.5-ha subplots was large and it decreased as plot size increased. Most of the variation in the distribution of birds among subplots was related to variation in the habitat.

In addition to the effects of plot size on census results, the choice of an appropriate size involves consideration of factors such as grid size, sampling speed and time available for censusing. The optimal size in this open pine habitat was between 20 and 25 ha. Plots of this size can be surveyed easily in the early morning hours and would provide estimates of approximately 80% of the species seen on a plot three times as large. In the present study, plots of 6.5 ha provided estimates of only 40% (range 16% to 60%) of the species observed on 58.3 ha.

Rarefaction, a statistical technique, is applied here as a method of comparing species richness among plots of different size. If one standardizes the number of individuals to the lowest number in a set of plots to be compared, rarefaction can be used to determine the number of species expected in a sample of that size.

Avian ecology relies largely on censusing techniques for estimates of community composition and relative abundance of species. The standard techniques that are in regular use have specific advantages and disadvantages depending on the objectives of the study (Järvinen et al. 1977, Robbins 1978a). For regional surveys one might choose the point count (Järvinen 1978), frequency sampling (Blondel 1975), the transect method (Emlen 1977), or the breeding bird survey (Robbins 1978a). If the objective is to obtain detailed quantitative information about the avifauna in a specific habitat, spot-mapping on repeated visits probably gives the most accurate results (Svensson and Williamson 1969, Robbins 1978a). But even with this intensive method, censuses of breeding birds (Williams 1936) and wintering populations (Anon. 1947, 1950) as published in *American Birds* and elsewhere are subject to sources of error that are difficult to evaluate. Differences among observers (Enemar et al. 1978), time of day (Robbins 1972, Shields 1977), and season of the year (Järvinen et al. 1977) are recognized as possible biases (Berthold 1976), but the magnitude of their effects usually is unknown. Species/area effects are another source of variation that deserves attention. The number of species tends to increase as sampling area increases. This may be attributable to the heterogeneity of the habitat or to the effects of sampling (Connor and McCoy 1979).

Some studies have been based on comparisons among censuses taken on areas of different size without standardizing them to areas of equal size; others compare censuses taken on areas that are too small to support an adequate representation of the species of birds present. Recommendations for the size of a study area are available: 8–10 ha in wooded habitats (Anon. 1947, Kolb 1965, Webster 1966, International Bird Censusing Committee 1970), and 40–100 ha in open habitats (IBCC 1970). Most authors agree that, to obtain comparable accuracy, winter plots should be larger than breeding season plots in similar habitats. None of these references presents evidence on how much variation in population estimates is attributable to the size of the study plot.

We report here the results of a Winter Bird-Population Study (WBPS) made in an

FIGURE 1. The study site is a mature longleaf pine stand near Thomasville, Georgia, having an apparently uniform vegetation stucture.

open mature longleaf pine (*Pinus palustris*) forest in southern Georgia in January and February, 1979. We marked the area so that subsamples and combinations of subsamples could be considered as independent surveys for predicting the larger community of birds. The results are used to discuss factors involved in the choice of plot size in a bird survey.

METHODS

The study site is 2 mi south of Thomasville, Thomas County, Georgia, on Arcadia Plantation. It is one of the few remaining tracts of fully mature longleaf pine in the southeastern United States (Fig. 1). The natural occurrence of fire kept large areas of northern Florida and southern Georgia in this type of vegetation in prehistoric times (Komarek 1968). This site is now maintained as a natural area by the Tall Timbers Research Station and is burned annually.

The forest is composed mostly of trees that are 200, and some possibly 300, years old. A narrow strip of little-leaf titi (*Cyrilla parvifolia*) with some sweetgum (*Liquidambar styraciflua*) and swamp tupelo (*Nyssa biflora*) occurs in a wet area in the center of the site. This titi "stringer" and a few patches of winged sumac (*Rhus copallina*) and sapling bitternut hickory (*Carya cordiformis*) constitute the only shrubby areas on the site. The major ground cover species are bracken fern (*Pteridium aquilinum*), wiregrass (*Aristida stricta*), and runner oak (*Quercus pumila*). Clewell (1978) listed many of the herbaceous plants.

A 58.3-ha (144-acre) square area was divided using a compass and tape measure into nine 6.5-ha (16 acre) subunits. The bird survey was conducted following the methods described in *Audubon Field Notes* (Anon. 1947), Kolb (1965), Robbins (1972) and the IBCC (1970). The results are presented as a WBPS in *American Birds* (Engstrom 1980).

The size of 6.5 ha for the subplots was selected because it is similar to the 6.1-ha (15 acre) minimum suggested in *American Birds* for both breeding bird censuses and winter bird-population studies. The results for these smaller areas were compared and then combined to simulate the results of censuses on successively larger plots. The survey route followed an S-shaped pattern along a grid in which the lines were 128 m apart. Care was taken to record birds crossing subplot boundaries to minimize duplication. All parts of a subplot were within 64 m of the survey route. There are no special recommendations for the distance between grid lines for the route in winter bird-population studies, but the IBCC (1970) recommended 200 m for prairie and tundra and 50 m for closed forest habitats in the breeding season. C. Robbins (pers. comm.) recommends that the distance between lines should be less in winter studies than in the breeding season because birds of many species are less easily detected in winter. The walk along the route was timed so that each subplot was completed in 56 minutes. This was approximately 8.6 min/ha (3.5 min/acre). Robbins (1972) recommended 12.4 min/ha (5 min/acre) in closed forest habitats.

All surveys were started within ±4 minutes of sunrise, and averaged 3 hours and 45 minutes. A complete survey of all 58.3 ha took 8 hours on two days. Although spreading the survey over two days introduced some

TABLE 1. Survey results for each 6.5-ha subplot. Data are the number of individuals seen on nine surveys.

Species	Subplots F6	D6	B6	B4	D4	F4	F2	D2	B2	Total*
Wood Duck (*Aix sponsa*)	0	0	0	0	0	0	0	0	2	2
Red-tailed Hawk (*Buteo jamaicensis*)	0	0	0	0	0	1	1	1	0	2
Mourning Dove (*Zenaida macroura*)	1	2	0	2	5	0	2	2	7	20
Great Horned Owl (*Bubo virginianus*)	0	0	7	0	0	0	0	0	0	7
Common Flicker (*Colaptes auratus*)	0	3	3	2	9	0	6	10	4	34
Pileated Woodpecker (*Dryocopus pileatus*)	2	0	0	1	0	0	0	0	1	4
Red-bellied Woodpecker (*Melanerpes carolinus*)	5	7	7	5	10	9	17	6	10	72
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	3	3	6	5	3	6	3	5	3	30
Hairy Woodpecker (*Picoides villosus*)	0	0	0	0	0	1	0	0	0	1
Downy Woodpecker (*P. pubescens*)	1	0	0	0	0	1	0	0	1	3
Red-cockaded Woodpecker (*P. borealis*)	2	15	19	15	20	17	20	16	26	139
Eastern Phoebe (*Sayornis phoebe*)	0	0	0	0	1	0	0	0	0	1
Blue Jay (*Cyanocitta cristata*)	0	0	0	3	4	2	4	1	5	18
White-breasted Nuthatch (*Sitta carolinensis*)	3	7	7	5	17	7	7	9	12	66
Brown-headed Nuthatch (*Sitta pusilla*)	2	14	12	5	7	7	9	10	3	64
House Wren (*Troglodytes aedon*)	8	5	10	1	11	24	15	9	0	82
Carolina Wren (*Thryothorus ludovicianus*)	3	0	1	0	9	11	7	2	0	33
American Robin (*Turdus migratorius*)	3	20	5	16	20	2	1	2	3	72
Eastern Bluebird (*Sialia sialis*)	1	6	0	0	1	11	8	0	0	27
Ruby-crowned Kinglet (*Regulus calendula*)	0	0	0	0	0	0	1	0	0	1
Loggerhead Shrike (*Lanius ludovicianus*)	0	2	3	1	1	0	1	3	3	13
Solitary Vireo (*V. solitarius*)	0	3	1	1	2	0	1	0	2	19
Yellow-rumped Warbler (*Dendroica coronata*)	2	0	1	0	6	0	11	0	0	20
Pine Warbler (*D. pinus*)	12	15	15	4	7	9	11	14	16	95
Palm Warbler (*D. palmarum*)	4	7	2	4	1	0	3	0	0	21
Common Yellowthroat (*Geothlypis trichas*)	3	8	9	5	36	17	26	8	0	110
Eastern Meadowlark (*Sturnella magna*)	15	6	1	21	0	2	0	0	3	47
Red-winged Blackbird (*Agelaius phoeniceus*)	1	0	0	150	1	250	0	45	90	537
Cardinal (*Cardinalis cardinalis*)	0	0	0	0	5	0	2	0	0	7
American Goldfinch (*Carduelis tristis*)	0	0	1	1	7	0	0	0	0	9
Rufous-sided Towhee (*Pipilo erythrophthalmus*)	2	2	6	1	33	13	63	30	0	146
Swamp Sparrow (*Melospiza georgiana*)	0	0	8	1	0	0	3	0	0	12
SUBPLOT TOTALS										
Number of individuals on nine trips	73	125	124	249	216	390	222	173	191	
Total # of species (32/58.3 ha)	19	17	20	21	23	18	23	17	17	
Average # individuals/trip**	8	14	14	28	24	43	25	19	21	
Species for which there was an average of at least one individual per trip, rounded (25/58.3 ha)†	4	11	12	9	15	12	12	11	7	

* This is the number of individuals seen during nine surveys for the entire 58.3-ha plot. The sum of subplot values sometimes exceeds the grand total because some individuals (52) were observed crossing over subplot boundaries and were counted more than once.
** Individuals recorded on all trips divided by nine, rounded to the nearest whole number.
† Species for which the number of individuals divided by the number of trips is less than 0.5 are omitted.

variation, it was the only way to cover the entire plot during morning hours. The 58.3-ha plot was completely surveyed nine times in January and February, 1979. The average minimum temperature of census dates was 1.1°C and the average maximum was 13.3°C. All surveys were made by the senior author.

The order in which the subplots were surveyed was arranged to eliminate between-subplot variation in detectability with time of day. To reduce the bias caused by changes in bird detectability during the morning, all subplots were sampled the same number of times, and during the same parts of the morning, but on different days (see Methods). Friedman's non-parametric rank sums test (Hollander and Wolfe 1973) showed that differences in the number of birds detected at different hours of the morning were statistically significant. The number of birds observed decreased with hour of the morning.

To assess variation in the structure of the habitat, 45 0.04-ha (0.1-acre) circular samples were taken, five randomly selected on each of the nine subplots according to the method recommended by James and Shugart (1970).

RESULTS

CENSUS RESULTS

We found a total of 32 species in nine complete censuses (Table 1). The number of individual birds seen on each subplot varied from an average of 8 per trip to an average of 43 per trip and the total number of species on each subplot varied from 17 to 23. Data are reported in *American Birds* in terms of the average number of individuals seen of each species. Because these averages are rounded to the nearest whole number, all species having an average of ≥ 0.5 individuals are recorded as having been seen at least once per trip. The number of species seen at least once per trip (rounded) per 6.5-ha subplot varied from 4 to 15, and 25 species were seen on the entire plot.

TABLE 2. Quantitative habitat analysis for nine 6.5-ha subplots.

	F6	D6	B6	B4	D4	F4	F2	D2	B2
Trees 3 inches DBH and over*	90	36	62	60	50	56	62	44	42
Total basal area (ft^2/acre at breast height)	59.6	65.6	79.6	95.8	49.4	62	58.8	87.4	63.6
Percent longleaf pine	98	95	87	93	96	96	100	100	95
Longleaf pine									
trees/acre	88	34	54	56	48	54	62	44	40
relative density (%)**	98	95	87	93	96	96	100	100	95
relative dominance (%)†	96	91	82	92	99	90	100	100	99
frequency (%)††	100	100	100	80	100	100	100	100	100
Size class A (3–6" DBH)									
trees/acre	40	6	12	0	14	16	12	0	0
relative density (%)	44	8	19	0	28	29	19	0	0
basal area (ft^2/acre)	6	0.6	1.2	0	1.4	1.6	1.2	0	0
relative dominance (%)	10	0.5	2	0	3	3	2	0	0
Size class B (6–9")									
trees/acre	10	10	6	0	4	12	18	0	6
relative density (%)	11	13	10	0	8	21	29	0	14
basal area (ft^2/acre)	2	2	1.8	0	1.2	3.6	5.4	0	1.8
relative dominance (%)	5	3	2	0	2	6	9	0	3
Size class C (9–15")									
trees/acre	24	12	14	20	16	4	8	12	18
relative density (%)	26	15	22	33	32	7	13	27	43
basal area (ft^2/acre)	19.2	9.6	11.2	16	12.8	3.2	6.4	9.6	7.2
relative dominance (%)	32	8	14	17	26	5	11	11	23
Size class D (15–21")									
trees/acre	14	40	24	34	12	17	22	22	12
relative density (%)	15	51	39	57	24	29	36	50	29
basal area (ft^2/acre)	25.2	72	43.2	61.2	21.6	28.8	39.6	39.4	21.6
relative dominance (%)	42	62	54	64	44	46	67	45	34
Size class E (21–27")									
trees/acre	2	10	4	6	4	8	2	6	2
relative density (%)	4	13	7	10	8	14	3	14	5
basal area (ft^2/acre)	6.2	31	12.4	18.6	12.4	24.8	6.2	18.6	6.2
relative dominance (%)	10	27	16	19	25	40	11	21	10
Size class F (27–33")									
trees/acre	0	0	2	0	0	0	0	4	4
relative density (%)	0	0	3	0	0	0	0	9	9
basal area (ft^2/acre)	0	0	9.8	0	0	0	0	19.6	19.6
relative dominance (%)	0	0	12	0	0	0	0	31	31
Canopy cover (%)	35	51	66	62	36	23	52	45	45
Shrub stems (No./0.1 acre)	0	10	0	0	2570	0	0	520	210
Ground cover (%)	100	100	100	100	100	100	100	100	100

* Based on 45 0.1-acre circular samples, five per subplot.
** Percent of total number of trees of all species or within all size classes.
† Percent of total basal area.
†† Percent of circles having this species.

Quantitative habitat descriptions for each subplot plus a cumulative description for the entire plot (Table 2) showed larger variations than we expected. This was apparent in the density of large trees (range in number of trees >21 inches DBH/acre, 2–10), the number of shrub stems (range in number of shrub stems/acre, 0–2,570), and the percent canopy cover (23–66%). A comparison of the habitat data with the bird distribution among the subplots (Tables 1 and 2) suggests the basis for some of the variation in bird density. For instance, subplot F6 had the fewest birds and had a low number of large trees and few shrubs. Subplots D4 and F2 had the highest density of birds in the area. Most of the birds were in the titi stringer in D4 and in the *Sassafras* and *Rhus* in F2. Red-winged Blackbirds roosted in subplots B4 and F4 and fed together in subplot B2 (Table 1). Common Yellowthroats and Rufous-sided Towhees showed high variation in density between subplots, usually occurring in areas where there was

Sassafras and *Rhus* (subplots F2 and D2). The Great Horned Owls in subplot B6 were nesting. Four clans of Red-cockaded Woodpeckers, each with 4–5 birds inhabited the study area and two more clans roosted nearby. This is an exceptionally high density, indicating that the area may be optimal habitat for the species. Red-cockaded Woodpeckers were occasionally seen in mixed flocks with Brown-headed and White-breasted nuthatches, Pine Warblers, and Solitary Vireos. Cardinals, American Goldfinches, and Swamp Sparrows were all seen most often in or near the titi stringer in the center of the plot. The Eastern Meadowlarks occurred in flocks and appeared to roost at night beneath the thick carpet of wiregrass.

TABLE 3. The mean, range, and standard deviation of the number of individuals and species in all possible combinations (N) of subplots that can be made to form different sizes of plots. The estimated number of species seen an average of at least once per trip, E(S), for samples of this number of individuals was determined by rarefaction.

Plot size	N		Mean	Range
6.5 ha	9	Ind.	22	8–43
(16 acres)		Species*	10	4–15
		E(S)	11	5.7–15.6
13 ha	36	Ind.	43	22–71
(32 acres)		Species	16	12–20
		E(S)	15.6	11.0–19.0
19.4 ha	84	Ind.	65	28–95
(48 acres)		Species	19	15–23
		E(S)	18.4	12.6–20.9
25.9 ha	126	Ind.	87	55–120
(64 acres)		Species	21	18–25
		E(S)	20.4	17.3–22.4
32.4 ha	126	Ind.	109	76–141
(80 acres)		Species	23	19–25
		E(S)	21.8	19.5–23.4
38.9 ha	84	Ind.	130	100–160
(96 acres)		Species	23	20–25
		E(S)	23.0	21.3–24.1
45.3 ha	36	Ind.	152	125–174
(112 acres)		Species	24	21–25
		E(S)	23.8	22.7–24.5
51.8 ha	9	Ind.	174	152–189
(128 acres)		Species	25	23–25
		E(S)	24.6	23.8–25.0
58.3 ha	1	Ind.	189	
(144 acres)		Species	25	

* Species seen an average of once per trip.

ESTIMATES OF THE COMMUNITY BASED ON SAMPLES OF DIFFERENT SIZE

The subplot data were treated as nine independent 6.5-ha replicates. The results of all possible combinations of the subplot data are summarized in Table 3. Combinations of adjacent subplots were considered but the results were very close to the results of all-possible combinations. Birds observed crossing over subplot boundaries were subtracted from the combined results. The average number of species seen at least once per trip based on all possible combinations of subplots increased from 10 to 25 as plot size increased from 6.5 to 58.3 hectares (Table 3). The range of 11 species (4–15) in the number of species in the subplots is disturbingly large. The range decreases regularly with increasing area. The average number of species seen on the nine subplots was 10, which is only 40% of the number of species seen on the full area. The sample size required to obtain 80% of the species on 58.3 ha is between 19.4 ha and 25.9 ha.

RAREFACTION

Rarefaction is a statistical technique that can be used to generate a curve of the expected number of species in smaller samples of individuals than the original sample (Sanders 1968, Hurlbert 1971, Fager 1972, Simberloff 1978). Given N individuals distributed in S species, the expected number of species [E(S)] and its standard deviation can be calculated. Heck et al. (1975) used this technique to assess sampling efficiency by comparing effort with sampling results.

We calculated a rarefaction curve (Fig. 2) for the avian community, using the relative abundance of all species seen at least once per census trip on the study area. The rarefaction curve shows the rate of accumulation of new species with increasing number of individuals. The number of species on plots of different sizes was estimated by rarefaction, using the number of individuals from the all-possible combinations data (Table 3). The average number of species and individuals from the all-possible combinations data for each size class are added to the rarefaction curve (Fig. 2). The number of species determined by all possible combinations of the 6.5-ha subunits is close to the number of species estimated by rarefaction (Fig. 2 and Table 3).

Densities reported in the WBPS are standardized to densities expected on 40.5 ha (100 acres) and on 1 km^2. To investigate the effects of this procedure, we standardized the density of individuals to 40.5 ha for all of the progressively larger sample areas. The estimated number of species, E(S), was calculated by rarefaction for these standardized densities (Table 4). Variation in the

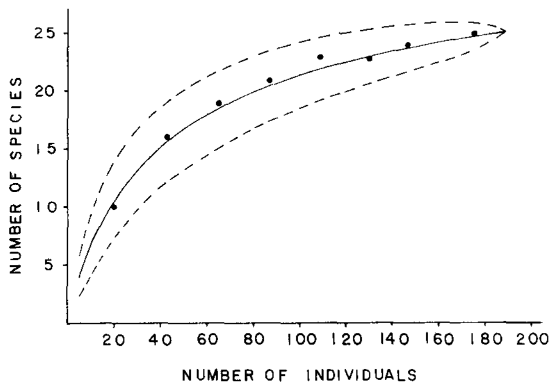

FIGURE 2. The rarefaction curve is generated from the relative distribution of the total number of individuals among the species on the entire 58.3-ha plot. The dashed line is two standard deviations from the curve. The average number of species and individuals from all possible combinations of the 6.5-ha subunits are superimposed on the rarefaction curve. Thus the dots from left to right are the average numbers of individuals and species for the eight area classes shown in Table 3.

TABLE 4. The number of individuals per trip per 40.5 ha (100 acres) in plot size classes, as determined by all possible combinations (N) of the nine 6.5-ha subplot, and the number of species, E(S), estimated by rarefaction corresponding to the estimated number of individuals.

Plot size	N		Range
6.5 ha	9	Ind/40.5 ha	50–269
(16 acres)		E(S)/40.5 ha	16.6–*
13 ha	36	Ind/40.5 ha	69–222
(32 acres)		E(S)/40.5 ha	18.8–*
19.4 ha	84	Ind/40.5 ha	75–200
(48 acres)		E(S)/40.5 ha	19.1–*
25.9 ha	126	Ind/40.5 ha	86–188
(64 acres)		E(S)/40.5 ha	20.3–25.0
32.4 ha	126	Ind/40.5 ha	95–176
(80 acres)		E(S)/40.5 ha	20.9–24.6
38.9 ha	84	Ind/40.5 ha	104–167
(96 acres)		E(S)/40.5 ha	21.5–24.3
45.3 ha	36	Ind/40.5 ha	111–155
(112 acres)		E(S)/40.5 ha	21.9–24.1
51.8 ha	9	Ind/40.5 ha	119–147
(128 acres)		E(S)/40.5 ha	22.4–23.6

* The number of individuals estimated by all possible combinations of the data exceeds the number of individuals actually observed in the 58.3-ha plot, so no estimate of the number of species can be made by rarefaction.

number of individuals per 40.5 ha estimated from the subplots was large. This variation decreased as the plot size increased. Rarefaction cannot be used to estimate the number of species found in a sample larger than the observed number of individuals. The number of individuals standardized to 40.5 ha in the three smallest plot sizes exceeds the actual sample found on the 58.3 ha plot, so the number of species cannot be estimated for these densities.

DISCUSSION

We think that standardization of methods and considerations of species/area effects should be given more attention in studies involving bird censuses. The classic conclusion of MacArthur and MacArthur (1961) that bird species diversity during the breeding season increases with foliage height diversity was based on comparisons among 2-ha (5-acre) plots. Willson (1974) based her study of habitat structure on 21 areas varying in size from 5 to 25 ha. Cody (1974) based his investigation of community structure on plots varying from 2 to 6 ha. Rarefaction is the only method we know by which species richness can be compared between plots of different size and density.

The apparent uniformity of the habitat in our study (Fig. 1) was deceptive. This is consistent with the results of a study of the species/area relationship by Kilburn (1966) in jack pine forests (*Pinus banksiana*) in the midwestern U.S. Our vegetation analysis shows that estimates of the density of the trees by size class, the percent canopy cover, and the distribution of shrubs varied substantially among the subplots (Table 2). Variation in the distribution of the birds among subplots appears to be attributable largely to variation in the structure of the habitat. This variation makes us cautious about interpreting the species richness results of wintering bird population studies based on small study plots.

Extrapolation of densities from small plots to standards such as the 40.5 ha and 1 km² as recommended in *American Birds* magnifies variation in density to an unreasonable level. The range in the number of individuals extrapolated to 100 acres from the subplot results is 50–269 (Table 4). Furthermore, there is no way to extrapolate an estimated number for species richness. A better means of comparing the species richness of bird communities is to standardize census data to equal numbers of individuals and to derive an estimated number of species by rarefaction. The number of individuals on plots above a minimum size, 10 ha for example, can be corrected to that minimum level, and then the number of species can be estimated for the standard size. We have examined how bird density and species richness vary on small plots. Rarefaction ignores this variability and can only supply species richness estimates as if the habitat were homogeneous. While this should be recognized, rarefaction is still preferable to standardizing densities to 40.5 ha and reporting species richness for a different sized area.

Certain general concepts in ecology can be examined with data generated by the Breeding Bird Censuses and the Winter Bird-Population Studies. To date, remarkably little analysis has been applied to them. Udvardy (1957) and Webster (1966) used published BBC's and WBPS's respectively to look at species number and avian density in the eastern and western United States, plotting species number against latitude and longitude to indicate geographic diversity gradients. Lynch and Whitcomb (1977) studied population trends of migrant warblers occupying the interior of forests using long-term data from *American Birds* BBC's. They selected eight BBC's on plots of 7–32 ha (18–80 acres) in Maryland, Michigan, and Georgia, some having data dating back to 1947. Robbins (1978b) has used the vegetation data to predict the abundance of particular bird species in a given forest environment.

The choice of plot size involves a compromise. Large plots require more time to census, yet small plots have more variable results. The 58.3 ha plot surveyed in this study was chosen for experimental purposes, not as an optimal size. The disadvantage of so large a plot is that a full census requires two mornings to complete. Important criteria for the determination of avian census plot size are (1) use of a grid distance that allows good visibility in the habitat, (2) ability to complete a census or survey in the early morning, and (3) maximization of plot size so the avifauna is adequately represented. A plot size of 20–25 ha in open pine habitat was necessary to sample 80% of the species observed on the 58.3-ha plot. We feel that an area of 20–25 ha is a reasonable size because it provides an adequate sample of the avifauna and it can be surveyed easily in a morning. In 1979, 20 of 120 WBPS's published in *American Birds* were conducted on plots smaller than 8 ha (20 acres). A plot this small on our study area would have been insufficient to represent the avifauna of the habitat.

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RECENT PUBLICATIONS

Papers in Avian Paleontology Honoring Hildegarde Howard.—Edited by Kenneth E. Campbell, Jr. 1980. Contributions in Science No. 330, Natural History Museum of Los Angeles County. 260 p. Paper cover. $20.00 plus $1.25 for handling and postage. Source: Bookshop, Museum of Natural History, 900 Exposition Blvd., Los Angeles, CA 90007. "Nineteen papers in avian paleontology—including theoretical aspects, faunal studies, reviews of specific groups, the description of several new forms, and archaeological studies—" are presented in this festschrift. Preceding these are appreciations of Hildegarde Howard by Theodore Downs, Jean Delacour, and Herbert Friedmann; the bibliography of Dr. Howard and an index to avian taxa that she described. Also included are the famous illustrations of avian osteology, drawn by Frieda Abernathy, from "The Avifauna of the Emeryville Shellmound," one of Howard's most important papers. The articles themselves have been contributed by most of today's leading paleornithologists, making the volume a fitting tribute to Dr. Howard and a significant collection for those who study the fossil history of birds. They are individually furnished with illustrations and references. Included among them is a description, by Campbell and E. P. Tonni, of a tremendous new teratorn from the late Miocene of Argentina. With an estimated wingspan of 6.5 to 7.5 m, it was the largest flying bird known to science.

Relationships and Evolution of Flamingos (Aves: Phoenicopteridae).—Storrs L. Olson and Alan Feduccia. 1980. Smithsonian Contributions to Zoology No. 316, Smithsonian Institution Press, Washington, D.C. 73 p. Paper cover. This technical paper re-examines the problem of the ancestral relationship of the flamingos—whether to storks or ducks as long disputed, or to shorebirds as recently suggested. Previous anatomical information is reviewed and the appendicular myology of the Australian Banded Stilt (*Cladorhynchus leucocephalus*) is described and discussed. Evidence from osteology, natal down, oology, parasitology, life history, and behavior is also considered. A new stilt-like flamingo from the early Middle Eocene, *Juncitarsus gracillimus*, is described and other aspects of paleontology of flamingos are discussed. The filter feeding apparatus of flamingos is shown to be entirely different from that of ducks and strikingly convergent toward that of baleen whales. Putting everything together, the authors conclude that the Phoenicopteridae are charadriiforms, most closely allied to the Recurvirostridae. Their case is carefully built from several directions and it appears to settle the question. Drawings, photographs, and references.

***Presbyornis* and the Origin of the Anseriformes (Aves: Charadriomorphae).**—Storrs L. Olson and Alan Feduccia. 1980. Smithsonian Contributions to Zoology No. 323, Smithsonian Institution Press, Washington, D.C. 24 p. Paper cover. The authors discredit evidence purportedly allying the Anseriformes with the Galliformes. Instead, from an examination of the Eocene fossil *Presbyornis*, particularly its filter-feeding apparatus, they propose that the Anseriformes evolved from the Charadriiformes. Along the way, they show that screamers are highly derived anseriforms, suggest that the major subgroups of anatids may need rearrangement, and propose a scenario for anseriform evolution. Their argument appears to rest on a thorough analysis, so it is likely to be controversial among avian systematists and paleontologists. Drawings, photographs, and references.