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EFFECTS OF NUMBER OF CIRCULAR PLOTS ON ESTIMATES OF AVIAN DENSITY AND SPECIES RICHNESS

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ABSTRACT.—We evaluated the effects of the number of census stations on estimates of avian density and species richness using the variable circular plot method. Data were collected in a variety of vegetation types, including coniferous and deciduous forests, shrublands, and uplands. Density estimates generally decreased with an increasing number of stations; however, density values in most habitats were fairly constant with as few as four stations censused four or five times each. The number of stations necessary to achieve a stable density estimate was related to the complexity of habitat. Inaccurate density estimates calculated for two stations on several sites were caused by gross underestimations of the effective detection distance for one or two species; these detection distances stabilized by four stations. Density estimates decreased slightly when sampling exceeded four stations, due to an increasing number of stations included in the calculations that reported zero values (i.e., species absent). The cumulative number of species observed increased with an increase in stations. We concluded that the optimum number of stations was a study specific problem, and should be based both on the complexity of the habitat and on the type of results needed. Guidelines for making such decisions are presented.

Of the methods available for censusing birds, the variable circular plot technique is one of the newest (Reynolds et al. 1980). A modification of J. T. Emlen's (1971) line transect method, this technique was developed to allow the observer to census from fixed points. Although applicable in all habitats, the method is especially suited to rough terrain.

Since the method is relatively new, little information is available for researchers to use in designing a study. Reynolds et al. (1980) noted that the number of stations necessary to calculate an accurate density for a species varied with the spatial distribution of individuals, its abundance, and its conspicuousness in various vegetation types. Thus, the researcher must be aware of the effects that the number of stations has on census results. This may be especially important when time is limiting and several different habitats must be assessed.

To establish guidelines for designing census procedures with this technique, we sought to determine the optimum number of stations for estimating density and species richness of birds. We approached this problem by analyzing data collected in several habitats in Oregon.

STUDY AREAS

Study areas ranged between 26 and 65 ha. We felt that 20 ha represented the smallest area that could be considered relatively continuous habitat; sites below that size are increasingly affected by the environment and associated avifauna of adjacent habitats. Therefore, our results should be interpreted as applying to areas of at least 20 ha.

The following is a brief description of the six areas chosen for study. Each site will be referred to by its associated mnemonic (in italics) throughout the text. A more thorough description of the vegetative zones characteristic of our study areas was given by Franklin and Dyrness (1973).

Site 1: The Early-growth Clearcut site (4-yr post-planting) was located at 30 m elevation in the Oregon Coast Range about 30 km west of Corvallis, Benton County, Oregon. The 30 ha site had an average slope of 35% and a northern exposure. The area was clearcut logged (all commercial and noncommercial trees were cut) in 1972. After logging, the site was prepared for planting by broadcast burning (1972) followed by herbicide treatment (1973); Douglas fir (*Pseudotsuga menziesii*) seedlings were hand planted in 1975. During our study, the vegetation was characterized by a dense (48% cover) and ubiquitous shrub layer dominated by salmonberry (*Rubus spectabilis*), thimbleberry (*R. parviflorus*), vine maple (*Acer circinatum*), and salal (*Gaultheria shallon*). Dominants in the low shrub-herb layer included sword-fern (*Polystichum munitum*), tanzy ragwort (*Senecio vulgaris*), foxglove (*Digitalis purpurea*), pearly everlasting, (*Anaphalis margaritacea*), Oregon oxalis (*Oxalis oregana*), and various grasses. Douglas-fir had not yet assumed a position of dominance (4% cover) and with an average height of 1.2 m was severely suppressed by the shrub layer. Red alder (*Alnus rubra*) provided the only vertical diversification on the site. About five distinct patches of alder averaging 4.0 m in height were scattered about on areas of soil disturbance and collectively composed 8% of the total cover.

Site 2: The Plantation Clearcut (7-yr post-planting) was located near the previous site at about 300 m elevation. Comprising 26 ha, the site had a gentle slope and northeast exposure. Clearcut logging took place in 1970; site preparation and planting with Douglas-fir followed in 1972. Because of brush that was retarding conifer growth, the entire site was aerial sprayed with phenoxy herbicides (2,4-D and 2,4,5-T) in 1975. This treatment effectively eliminated red alder and greatly reduced the cover and vigor of shrubs. As a result,

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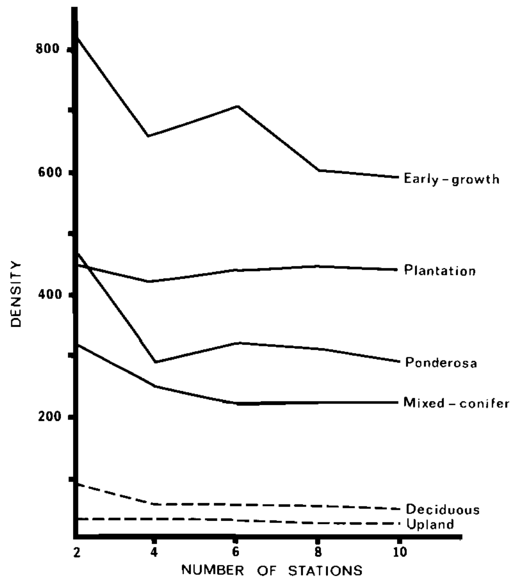

FIGURE 1. Density estimates obtained from census data collected at a varying number of stations for the six study sites (solid line = birds/40 ha; dashed line = birds/ha).

during our study, the site was dominated by a homogeneous cover (30%) of Douglas-fir. With an average height of 2.9 m, conifers supplied the only vertical structure on the site. Shrub cover (about 20%, primarily salmonberry, vine maple, and salal) was concentrated around the perimeter of the clearcut. The low shrub-herb layer was similar to that on the Early-growth Clearcut site.

Sites 3 and 4: The Deciduous Forest and Upland study areas were located on Miller Sands and West Sand Island, lower Columbia River, Oregon. Miller Sands, formed from deposition of dredged material, was located between river miles 22 to 25. West Sand Island, partially created from dredged material, was situated in Baker Bay, east of Cape Disappointment, Washington. A Deciduous Forest site and an Upland site were located on each island. Data were combined for our study (i.e., the two Deciduous Forest areas were lumped as were the two Upland areas) as no significant differences in avian communities were found between islands. The effective size of each study site was 35 ha.

In general, trees and shrubs occurred on low, mesic sites; higher elevations and drier soils typified Upland (forbs, grasses) plant communities. Red alder and willow (*Salix* spp.) composed 62% and 34%, respectively, of the Deciduous Forest overstory (over 5 m) on West Sand Island. Red alder (55%), willow (15%), and cottonwood (*Populus trichocarpa*) (16%) were the most abundant overstory trees on Miller Sands. Willow (46%), twinberry (*Lonicera involucrata*) (30%), and salmonberry (15%) were the dominant understory shrubs on West Sand Island. Salmonberry (36%) and elderberry (*Sambucus racemosa*) (25%) were the most abundant understory shrubs on Miller Sands. Principal habitat components for Miller Sands Upland were moss (37%) and forbs (24%). Grasses and sedges (26%), forbs (35%), and bare ground (20%) typified West Sand Island Upland.

Site 5: The Ponderosa Pine (*Pinus ponderosa*) study site was located in the southwestern Blue Mountains about 15 km north of John Day, Grant County, Oregon. It encompassed approximately 65 ha on a southwest-facing slope between 1450 and 1500 m elevation. Ponderosa pine seedlings and trees up to 10 m tall were abundant (55% canopy cover); large pine trees up to 1.2 m DBH and 30 to 40 m tall were scattered throughout the area and dominated the site. Western juniper (*Juniperus occidentalis*) was widespread (5% cover) but grew vigorously only on shallow, stony soils in forest openings. The edge of some of the openings also supported dense stands of mountain mahogany (*Cercocarpus ledifolius*) shrubs, 2 to 7 m tall (1% cover). Douglas-fir, grand fir (*Abies grandis*), and western larch (*Larix occidentalis*) were present but essentially confined to a cool, moist ravine on the southwest portion of the site (5% cover). Conspicuous species in the low shrub-herb layer included elk sedge (*Carex geyeri*), pinegrass (*Calamagrostis rubescens*), shinyleaf spiraea (*Spiraea betulifolia*), heart-leaf arnica (*Arnica cordifolia*), lupine (*Lupinus* spp.), and snowberry (*Symphoricarpos* spp.).

Site 6: The Mixed-conifer study site was located in the Wallowa-Whitman National Forest about 8 km west of Medical Springs, Union County, Oregon. The stand was approximately 45 ha in size and was situated on the southwest-facing slope of the Eagle Creek drainage. Elevation at the site ranged from 1500 to 1900 m. Although small openings were scattered throughout the stand, the site generally was densely forested (40–100% canopy closure) with trees of varied sizes providing a multi-layered canopy. The overstory was dominated by large (over 76 cm DBH, 25 to 35 m tall) Douglas-fir and ponderosa pine, while grand fir dominated the understory. Scouler willow (*Salix scouleriana*), 3 to 4 m tall, was sparsely distributed (less that 5% cover) throughout the area. Dominant species in the low shrub-herb layer were elk sedge, pinegrass, and heart-leaf arnica.

METHODS

We used the variable circular plot method (Reynolds et al. 1980) to census birds on each study area. Ten stations were established on each site. No station was closer than 100 m to the edge of adjacent habitat nor closer than 100 m to the next nearest station. Exceptions to these distances were made where a physical barrer (e.g., river) abruptly demarked the edge of the habitat. Censusing began at sunrise and ended 2 to 3 hrs later. On any given study site, count duration and number were the same at each station. Because of differences in vegetation structure and breeding phenologies of the birds between study sites, we varied counts per station (study site) from 4 to 5, and time per count from 8 to 10 minutes, respectively.

Bird densities were estimated from data taken at three combinations (replicates) each of 2, 4, 6, and 8 stations; only one estimate was possible for 10 stations. For example, for four stations, separate densities were derived from stations 1, 3, 5, 7; 2, 4, 6, 8;

TABLE 1
INTRA- AND INTERSTATION VARIATIONS IN DENSITY FOR A VARYING NUMBER OF STATIONS[a]

Site	Number of stations 2	4	6	8	10
Early-growth clearcut	ns	ns	ns	ns	ns
Plantation clearcut	*	ns	ns	ns	ns
Upland	ns	ns	ns	ns	ns
Deciduous forest	ns	ns	ns	ns	ns
Ponderosa pine	*	*	ns	ns	ns
Mixed-conifer	ns	ns	ns	ns	ns

[a] Nonsignificant interstation variations are indicated by horizontal lines; intrastation variation: ns = nonsignificant; * indicates $P < 0.05$.

TABLE 2
CUMULATIVE NUMBER OF SPECIES OBSERVED WITH A VARYING NUMBER OF STATIONS

Site	Number of stations 2	4	6	8	10
Early-growth clearcut	22	25	27	27	29
Plantation clearcut	17	21	24	25	26
Upland	15	21	23	23	27
Deciduous forest	15	18	20	20	22
Ponderosa pine	26	26	30	31	32
Mixed-conifer	19	25	25	26	27

and 1, 4, 7, 9. The effective radius of detection for each species was separately computed for each of the three groups of four stations. Densities and effective radii were computed for all possible combinations of 2, 4, 6, 8, and 10 stations for one study site, and results did not differ significantly from results based only on three combinations. A shortage of computer funds prevented similar treatment of results from other study sites.

The separate results from the three replicates were averaged to give an overall density estimate for each of the groups of stations. Analysis of variance (ANOVA) was used to determine if there were significant intra- or interstation variations in densities. The cumulative number of species observed also was determined for each group.

RESULTS

Densities generally decreased as the number of stations increased, until a stable point was reached with 4 or 6 stations, except for the Early-growth Clearcut site, where the density estimate did not stabilize until eight stations (Fig. 1). Significant interstation variations in densities were seen on only three sites—between 2 stations and 4 to 10 stations for the Early-growth Clearcut, Ponderosa Pine, and Deciduous Forest sites (Table 1). Although a qualitative judgment, these sites appeared to have a more patchy, or heterogeneous, vegetative structure than the other sites. Significant intrastation differences occurred when only 2 stations were used for density calculation, except for Ponderosa Pine, which exhibited such variation at 4 stations as well.

Although our data are too numerous to include here, perusal of results revealed that variation in the effective radius of detection of most species did not change appreciably with differing numbers of stations. Exceptions were obvious—on the Upland site, the effective radius for only one species, the Violet-green Swallow (*Tachycineta thalassina*), exhibited a marked fluctuation: for two stations, a radius of 10 m and a density of 8.0 birds per ha were calculated; whereas for 4 to 10 stations, the radius stabilized between 50 and 60 m, and the density between 1.5 and 2.0 birds per ha. The relatively high density estimate for this species, using only two stations, was responsible for the higher density value seen between two stations and 4 to 10 stations. A similar situation was responsible for the fluctuation noted on the Ponderosa Pine site: a radius of 15 m and a density of 349 birds per 40 ha were calculated for Chipping Sparrows (*Spizella passerina*); the radius was a constant 35 m, while the density ranged from 51 to 98 birds per 40 ha for 4 to 10 stations. Thus, for all sites, changes (errors) in the computed effective radius of birds were not the primary cause of interstation variation in density for four or more stations.

Not all species were observed at each station. If a species did not occur at a station, it was assigned a value of zero for that station. When densities were calculated for 2 or 4 stations, zero values had less of a dampening effect on overall density estimates as compared to their effect on 6 to 10 stations. Therefore, density estimates by species and overall site would be expected to decline with increasing numbers of stations until an equilibrium was reached between stations reporting a species and not reporting the species. This point should be attained sooner (fewer stations) on more homogeneous sites, where the dominant vegetation is more evenly distributed. This was evident for the Plantation and Early-growth Clearcut sites—no significant difference between stations was shown for the relatively homogeneous Plantation site, while on the more heterogeneous Early-growth Clearcut site, the density estimate did not stabilize until eight stations.

The cumulative number of species generally increased through 10 stations in all study areas (Table 2). It is not surprising that an increase in area censused would result in a more inclusive species list.

DISCUSSION

Our results show that two sources of error were responsible for unstable density estimates with a low number of stations. First, large errors with only two stations were caused by relatively small effective radii—an apparent result of small sample sizes. Second, after effective radii stabilized, densities continued to decline slightly as an increasing number of stations with zero values (i.e., species absent) were included in cumulative density calculations.

Following these results, we sought to establish broad guidelines which could be used to design a sampling scheme with the variable circular plot method. These guidelines fell into two general categories: (1) studies in which one needs only to estimate density based on the major components of the community and where estimates for minor (rare) species are relatively unimportant; and (2) studies in which the entire spectrum of the avifauna must be assessed regardless of relative densities. The former studies are often useful when simple baseline data must be collected from a variety of areas, and results need only to be within a fair degree of accuracy (e.g., inventories, study site selection). The latter involve projects where rare species are the object of concern, and/or differences within or between sites may be subtle (e.g., effects of various silvicultural treatments, guild analyses, community dynamics).

If a simple inventory is needed, one could place 2–4 stations in areas where the vegetation is relatively homogeneous; that is, a single physiognomic class of vegetation dominates the site with few pockets of obviously different vegetation. In patchy habitats, 4–6 stations would be indicated. However, if one needs to develop a detailed species list, 4–6 stations in homogeneous areas and 6–8 stations in more heterogeneous habitats would be required. The exact number of stations needed (e.g., 4 or 6) would depend upon the size of the study area and the extent of differing vegetation types. Caution should be used when placing only two stations; significant intrastation variations in densities were sometimes the result with such a low number of stations.

Placement (spacing) of stations is again dependent on the vegetative structure of the site. Even in homogeneous areas, few species were recorded at all 10 stations. Therefore, stations must be spaced throughout the area of interest and not concentrated along edges or points of easy access. We recommend a stratified random placement of stations (if the size of the study area permits). This is, if a site is 30% deciduous trees and 70% shrub cover, two stations should be placed in spots dominated by the tree component, and three or four stations scattered throughout the shrub cover.

The researcher should keep in mind that each study area should be censused four or five times during the period of interest (e.g., breeding season) to insure collection of an adequate sample size and to account for the phenologies of various species. Of course, data must always be scrutinized to determine whether the effective radii for rare species are reasonable.

We have thus shown that a study area need not be saturated with census stations before one can obtain a reasonably precise description of the avian community. It is possible to increase the scope of a study by careful placement of census stations. One might have adequate time to census two study areas in one morning or to collect other types of data while censusing.

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