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EFFECT OF TIME OF DAY AND TIME OF SEASON ON THE NUMBER OF OBSERVATIONS AND DENSITY ESTIMATES OF BREEDING BIRDS

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ABSTRACT.—In 1978 and 1979, a study was conducted to assess hourly and biweekly changes in number of detections and density estimates of birds during the breeding period. Bird detections, obtained from variable-circular-plot censuses, tended to decline from the first hour after sunrise to the fourth hour. Changes in bird detections among census hours are presented for selected species. Changes in detection distance estimates in relation to changes in the number detected are discussed.

Basic to all studies requiring estimates of bird abundance are census techniques that produce accurate, or at least, relative results. For most bird census methods, the timing of the counts is one factor that influences accuracy and comparability (J. T. Emlen 1971, Shields 1979). Bird detectability (the proportion of the population that is detected) changes during the day (Shields 1977) and varies among species (Robbins and Van Velzen 1967). Additionally, the number and kinds of birds observed on an area change within seasons (Holmes and Sturges 1975).

During the the breeding season, the number of birds detected and density estimates may be highest during the "middle" of the season (Järvinen et al. 1977b); detectability of many species peaks in the early morning (Robbins and Van Velzen 1967). Many observers restrict breeding bird censuses to morning hours during the "peak" of the breeding period when detections are highest and populations are presumably most stable. However, the duration of the morning census in relation to changes in the number detected requires further clarification. Also, information on changes in the number of birds detected throughout the breeding period would be useful in identifying periods when the detectable population is relatively stable. In 1978 and 1979, a study was conducted to determine if the number of detections and resulting density estimates of birds differed among four consecutive 1-hr periods after sunrise and among biweekly periods in the breeding season.

STUDY AREA

Censuses were conducted in a 65-ha ponderosa pine (*Pinus ponderosa*) stand located on a southwest slope between 1450 and 1600 m elevation in the Blue Mountains about 15 km north of John Day, Grant County, Oregon. Ponderosa pine seedlings and trees up to 10 m tall were abundant; pine trees up to 1.2 m dbh and 30 to 40 m tall dominated the site. Western juniper (*Juniperus occidentalis*) was common and widespread. Edges of some forest openings supported stands of mountain mahogany (*Cercocarpus ledifolius*) shrubs 2 to 7 m tall. Douglas fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), and western larch (*Larix occidentalis*) were present but confined to the southwest portion of the site. Conspicuous herbs and low shrubs included elk sedge (*Carex geyeri*), heart-leaf arnica (*Arnica cordifolia*), shiny-leaf spiraea (*Spiraea betulifolia*), and snowberry (*Symphoricarpos* sp.).

METHODS

Ten fixed stations were established approximately 100 m apart along a transect through the study area. Each year, in each of seven consecutive biweekly periods between late April and the end of July, six variable-circular-plot censuses (Reynolds et al. 1980) were conducted at the stations.

Censuses began at sunrise at an endmost station on the transect. The starting station for the first census in a 2-week period was determined by coin toss; starting stations were alternated for the subsequent censuses in the period. Each morning the transect was traversed twice, the second traverse in the reverse direction. Thus, censusing was conducted at 20 stations each morning (120 stations per biweekly period). Five consecutive stations (one station group) were visited within each census hour; hence, the censuses took about 4 hours to complete.

Wind velocity and air temperature were measured, and percent cloud cover was estimated at the beginning, middle, and end of the census. Censusing during cloudy weather was avoided as much as possible; however, to achieve six censuses per 2-week period, some censuses were conducted under cloudy skies. Most censuses were performed when wind velocity was less than 4.8 km/hr. Censusing was terminated if wind exceeded about 16 km/hr, or if rain or snow fell. Results of incomplete censuses were excluded from the analysis.

I counted birds for 10 min at each station but did not census during the 2- to 3-min walk between stations. Birds were counted if they were detected within or below the tree canopy. Birds that typically foraged in flight, such as swallows and swifts, were counted where observed flying above the trees. Species, estimated horizontal distance, behavior (singing or nonsinging), and mode of detection (visual, auditory, or both) were recorded for each detection. I was unable to distinguish songs from other vocalizations of Steller's Jays, nuthatches, Red Crossbills, and Pine Sis-

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TABLE 1
MEAN NUMBERS OF BIRD DETECTIONS AND DENSITY ESTIMATES PER CENSUS HOUR

Detection and density categories by year	Census hour 1	2	3	4
Total detections, 1978	73.2a[a]	71.1ab	67.4bc	62.8c
Total detections, 1979	88.2a	89.1a	84.6ab	79.5b
Total number of singing birds, 1978	55.1a	51.9ab	49.3bc	45.2c
Total number of singing birds, 1979	63.8a	62.2ab	57.0bc	55.4c
Total density of singing birds, 1978	59.4a	56.9a	57.1a	52.8a
Total density of singing birds, 1979	72.5a	70.4a	71.7a	69.6a

[a] Within rows, means not sharing the same letter differ significantly ($P < 0.05$).

kins. All detections of these species and drumming woodpeckers and Ruffed Grouse were recorded as singing birds.

Within each year, the singing-bird data for each species were categorized according to time of detection (first two or second two census hours). For each category an effective radius of detection, required for estimating densities, was derived following the procedure developed by Ramsey and Scott (1979). The number of birds per 40.5 ha (D) was calculated with the formula, $D = N(405{,}000)/5\pi(\rho)^2$, where N is the total number detected in each census hour (five stations) and ρ is the calculated effective radius in meters.

Factorial analysis of variance for a completely randomized design (Sokal and Rohlf 1969:343–356) was used to determine if mean numbers detected and mean density estimates differed significantly among census hours and biweekly periods. The two station groups were included as a factor in the analysis. Student-Newman-Keuls multiple comparison test (Sokal and Rohlf 1969:240–241) was employed to separate means in significant ANOVAs. Mean separation tests were performed at 5% level of significance.

RESULTS AND DISCUSSION

TIME OF DAY

For 1978, 11,526 bird detections were recorded; 74.4% (8515) were singing birds. In 1979, 14,336 detections were tallied; 70.5% (10,114) were singing birds.

Both years, total detections and total singing-bird detections decreased significantly ($P < 0.05$) from the first hour to the fourth hour (Table 1). Of the species with at least 100 detections, several showed relatively large (greater than 20%) changes in number detected between hourly periods (Table 2). Although detections usually decreased from hour 1 to hour 4, not all species showed statistically significant differences between mean hourly detections. All significant differences represented decreases in the number detected from the earlier hour. Numbers of some species remained remarkably constant among census hours (e.g., Chipping Sparrow in 1979). In 1979, detections of Steller's Jays increased from earlier to later census hours. Analysis of variance of the jay data indicated significantly different ($P < 0.05$) mean hourly detections, but the mean separation test failed to identify different hourly means.

Total density of singing birds declined during the morning; however, hourly means did not differ significantly (Table 1). Effective radii for most species decreased from the first two to the second two hours. Although fewer birds were detected in the last two hours, the estimated size of the area (area = $\pi\rho^2$) in which birds were counted also decreased. Some species did not exhibit the trend of shorter effective radius with fewer detections, or conversely, longer distances with more detections. For example, in 1979, detections of Clark's Nutcrackers declined by 41% in the last two hours, but the estimated census area increased by 34%. In 1978, Hermit Thrush detections increased by 47% while the estimated census area decreased by 27%. Relatively large hourly changes in numbers detected for both species were not significantly different ($P > 0.05$); mean density estimates, however, differed significantly among census hours.

Large changes in detectability during the morning census would confound results of studies designed to monitor absolute or relative changes in observed bird abundance caused by factors other than time of census. However, changes in the number of detections during the morning may not dictate corresponding changes in density estimates unless effective radius is directly and positively correlated to number of detections. Results for some species indicate that there might be a compensatory relationship between number of detections and effective radius.

Changes in frequency and loudness of songs during the census could account for changes in effective radius, assuming that techniques for estimating distances to birds and calculating radii are sensitive to subtle changes in bird behavior and are accurate. Ramsey and Scott's (1979) model for estimating effective radii assumes that birds are "independently" and "uniformly" distributed over the census area "according to a

TABLE 2
PERCENT CHANGE IN THE NUMBER OF SINGING BIRDS DETECTED BETWEEN CENSUS HOURS[a]

Species	n	Hours after sunrise 1–2	2–3	3–4	1–3	2–4	1–4
Ruffed Grouse	107	−19	−7	−44	−25	−48	−58[b]
(*Bonasa umbellus*)	148	−33	+11	−44	−25	−37	−58[b]
Common Flicker	164	−4	−6	−61[b]	−10	−63[b]	−65[b]
(*Colaptes auratus*)	89	—	—	—	—	—	—
Empidonax Flycatcher	1189	+1	−11	−11	−10	−21[b]	−20[b]
(*Empidonax* sp.)	1202	−11	−12	−4	−22	−16	−25[b]
Steller's Jay	68	—	—	—	—	—	—
(*Cyanocitta stelleri*)	186	+109	+19	+2	+148	+21	+152
Clark's Nutcracker	11	—	—	—	—	—	—
(*Nucifraga columbiana*)	154	+26	−50	+11	−37	−44	−30
Mountain Chickadee	356	−44[b]	−6	−16	−48[b]	−22	−56[b]
(*Parus gambeli*)	289	−26[b]	−29	+4	−48[b]	−26	−56[b]
White-breasted Nuthatch	306	−10	−19	−10	−27	−27	−34
(*Sitta carolinensis*)	318	−18	−2	−19	−20	−21	−35
Red-breasted Nuthatch	115	+21	−20	−18	−3	−34	−21
(*Sitta canadensis*)	1247	+6	+3	−6	+9	−2	+3
Brown Creeper	193	+7	−28	−30	−23	−49[b]	−46[b]
(*Certhia familiaris*)	205	−18	+4	−19	−15	−16	−31
American Robin	271	+1	−3	−28	−1	−30	−29
(*Turdus migratorius*)	170	−21	−7	+3	−27	−29	−25
Hermit Thrush	222	+57	+31	−17	+106	+9	+71
(*Catharus guttatus*)	238	+19	+11	−26	+32	−17	−2
Solitary Vireo	354	+8	0	−12	+8	−12	−5
(*Vireo solitarius*)	274	+16	−26	+12	−14	−18	−4
Yellow-rumped Warbler	740	+1	−6	−6	−5	−11	−10
(*Dendroica coronata*)	802	+17	−16	−7	−2	−22	−9
Western Tanager	615	−15	−1	−14	−16	−15	−28
(*Piranga ludoviciana*)	490	−25	−5	−9	−29	−14	−35
Cassin's Finch	1228	−12	−6	+1	−17	−4	−16
(*Carpodacus cassinii*)	1291	−7	−6	+8	−12	+2	−5
Pine Siskin	145	−3	+15	+5	+12	+21	+18
(*Carduelis pinus*)	66	—	—	—	—	—	—
Red Crossbill	328	−11	+18	−24	+5	−10	−26
(*Loxia curvirostra*)	715	−13	−12	−5	−23	−16	−27
Green-tailed Towhee	210	−10	−18	+9	−26	−11	−20
(*Pipilo chlorurus*)	228	+29	−31	+8	−11	−25	−4
Dark-eyed Junco	845	−13	+1	+10	−14	+11	−3
(*Junco hyemalis*)	731	−9	−8	+26	−16	+16	+6
Chipping Sparrow	665	+23	−2	−3	+20	−6	+16
(*Spizella passerina*)	922	+3	−2	−3	0	−5	−2

[a] Percentages depict changes from the earlier hour; within species, values in upper row are for 1978, lower row for 1979.
[b] Significantly different ($P < 0.05$) mean numbers detected.

random process." Further, they assume that distances to birds are estimated "without error." Certainly these assumptions are not strictly met; moreover, not only is distance estimation fallible, the magnitude and direction of the errors are probably inconsistent among observations within species. The influence of unfulfilled assumptions on estimates of effective

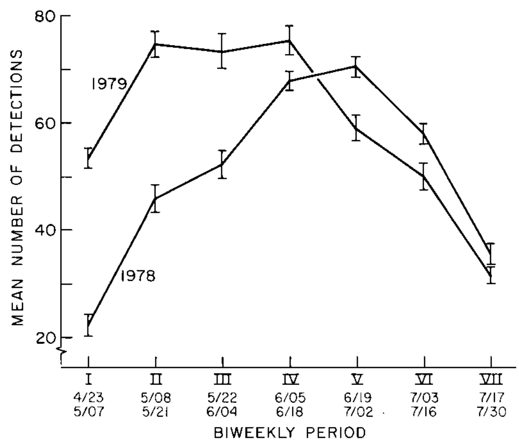

FIGURE 1. Mean numbers and standard errors of singing birds detected in seven biweekly periods. Dates shown are for 1978; 1979 dates were two days later.

radius may mask any likely compensatory effects due to changes in bird behavior. Results for species that deviated from the compensatory relationship may represent varying degrees of the effects of violations of the assumptions. Further investigation of interactions between number and effective radius seems warranted because several species exhibited a compensatory relationship.

Time of Season

For 1978, peak numbers of singing birds occurred in June; peak numbers in 1979 were recorded between mid-May and mid-June (Fig. 1). Yearly patterns of biweekly changes in total density of singing birds and total detections were similar to the patterns shown in Figure 1. Within years, mean detections of singing birds were similar ($P > 0.05$) among peak periods (IV and V in 1978 and II, III, and IV in 1979; Fig. 1), but were significantly greater ($P < 0.05$) than means for other periods.

Species listed in Table 2 exhibited statistically significant ($P < 0.05$) changes in number of detections among biweekly periods. However, patterns of observed changes in detections through time varied considerably among species. Generally, detections of resident species were highest in May; numbers of migrants usually peaked in June. Ruffed Grouse (a resident species), for example, were undetectable after mid-June in both years. Detections of singing Cassin's Finches, another resident species, decreased dramatically after the second or third biweekly period. Yet Western Tanager, a migrant, did not arrive on the area until mid-May.

To obtain data representative of the structure of a breeding bird community, censuses should be conducted throughout most of the breeding season. Abundance estimates for some species would be severely underestimated (and other species missed entirely) if censusing was restricted to periods of peak detections. Additionally, because of rather large changes in detections among biweekly periods (and perhaps among weeks), an estimate of average seasonal abundance for most species would be misleading. Results of this study indicate that if abundance estimates are to be relative among species in the same community or within species among communities, the researcher must account for changes in detectability during the morning census and changes in abundance estimates during the breeding period.

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