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INFLUENCE OF SAMPLE SIZE ON INTERPRETATIONS OF FORAGING PATTERNS BY CHESTNUT-BACKED CHICKADEES

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Abstract. We used sequential sampling techniques and statistical estimation of sample size to analyze the influence of sample size on interpretations of seasonal patterns of foraging by a resident population of Chestnut-backed Chickadees (*Parus rufescens*). We found that estimates of central tendency and dispersion for use of tree species, use of foraging substrate, and foraging behavior stabilized when 40 or more samples were used and that 30–50 samples were usually required for 95% confidence that an estimated mean would be within 10% of the mean of the entire sample. Although seasonal patterns obtained from two month and one month sampling periods were similar, the one month period provided greater information on changes in foraging patterns.

Key Words: Sample size analysis; seasonal foraging patterns; use of tree species; use of substrates; foraging behavior; Chestnut-backed Chickadee.

Variations in sample size can have a strong and potentially confounding influence on observed patterns of behavior (Kerlinger 1986:109); yet, little attention has been paid to the influence of sample size on analyses of avian foraging behavior. There are techniques for determining the minimum number of samples needed to see whether an estimate of a parameter falls within a selected confidence interval (see Cochran 1977, Scheaffer et al. 1986, and references therein). Until recently, however, ornithologists have generally neglected the use of statistical and graphical procedures for assessing factors that influence analyses of foraging behavior and habitat use (but see Wagner 1981a; Morrison 1984a, b; Block et al. 1987). Typically, most investigators collect as many samples as possible and then base their analysis on all samples collected, without regard to the adequacy of their sample size. This study was designed to expand upon Morrison (1984a) by extending the assessment of the influence of sample size to include seasonal changes in foraging behavior. Using the Chestnut-backed Chickadee (*Parus rufescens*) as an example, our objectives were to (1) determine the number of samples required for obtaining precise (based on the stability of means and variances) estimates of foraging behavior during different times of the year, and (2) evaluate how different time scales affect the outcome of patterns of seasonal changes in the use of tree species, use of foraging substrates, and foraging behaviors.

METHODS

STUDY AREA

We studied the foraging behavior and habitat use of Chestnut-backed Chickadees in the mixed-conifer forest zone of the western Sierra Nevada approximately 8 km east of Georgetown in El Dorado County from May 1986 through April 1987. Data were collected on and around the Blodgett Forest Research Station, University of California, at approximately 1100 meters elevation. This area is a mature mixed-conifer second-growth forest dominated by Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), incense cedar (*Calocedrus decurrens*), ponderosa pine (*Pinus ponderosa*), sugar pine (*P. lambertiana*) and California black oak (*Quercus kelloggii*). See Morrison et al. (1986) for a description of the study area.

DATA COLLECTION

The data used in this study were collected as part of an ongoing study of seasonal variation in foraging and habitat use by chickadees in the western Sierra Nevada. Observers walked random transects through the forest and recorded timed (8–30 s) observations of foraging chickadees. The observer waited a minimum of 10 s after seeing the bird, and then recorded a series of variables which corresponded to the tree species, substrate, and mode of foraging. We used the focal animal technique described by Altmann (1974) and Martin and Bateson (1986). Each recorded observation consisted of between two and ten records, or lines of data. Each time a bird changed tree species, substrate, foraging mode, or foraging height, a new record, or line of data, was added to the observation until the bird was lost from sight. Thus, each observation consisted of 1–9 sequential records of foraging observations. Each sequential series of 1–9 foraging records was treated as a single (N = 1) sample (see Data Analysis section below).

When flocks were encountered, we allowed at least 10 min to elapse between recording foraging observations. At Blodgett, chickadees forage in flocks from July until late March or April, and as solitary birds or pairs during nest building and breeding (mid to late April through early July; Brennan, pers. obs.). Thus, the detectability of foraging chickadees varied during the annual cycle. During the breeding season, most foraging observations were of breeding birds near (within 100 m) nests. Foraging observations of family groups (parents and fledglings) make up a major part of the July and August observations. Family groups of chickadees and mixed species-flocks were treated in a similar manner when foraging observations were made. Mixed flocks of Chestnut-backs and other species (e.g., Mountain Chickadee [*P. gambeli*], Red-breasted Nuthatch [*Sitta canadensis*], Golden-crowned Kinglet [*Re-*

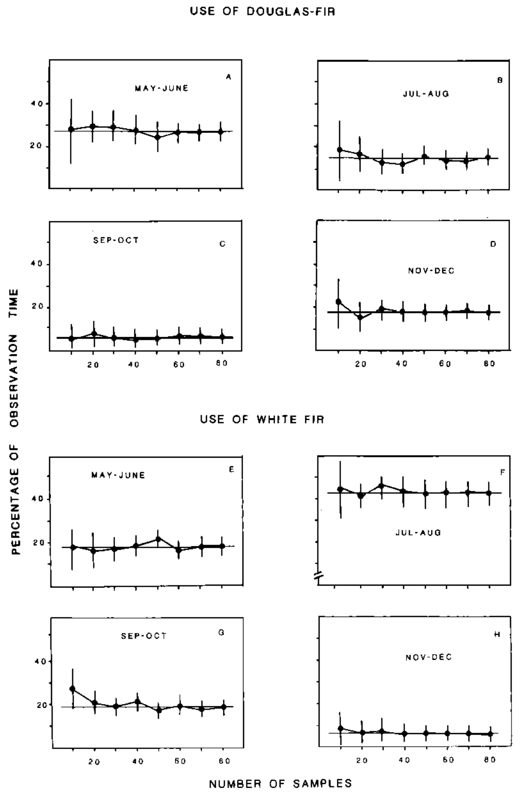

FIGURE 1. Percent use of two tree species (Douglas-fir and white fir) by Chestnut-backed Chickadees during four different sampling periods at Blodgett Forest Research Station, 1986–1987. Solid dots represent mean values at sample sizes ranging from 10 to 80 observations, vertical bars represent one standard deviation. Horizontal lines represent means calculated from all 80 samples.

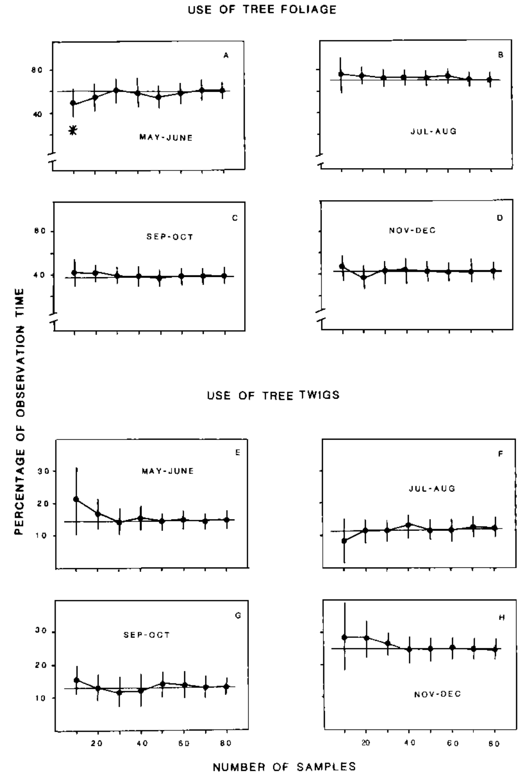

FIGURE 2. Percent use of two foraging substrates (tree foliage and tree twigs) by Chestnut-backed Chickadees during four different sampling periods at Blodgett forest Research Station, 1986–1987. Symbols as in Figure 1. Asterisks denote means that were statistically significant from the remaining homogeneous subset (P < 0.05, SNK-ANOVA).

gulus satrapa]) also foraged on the study area for much of the year.

Observations were made during all daylight hours and under the range of climatic conditions of the western Sierra Nevada (30°C during summer to freezing rain and snow in winter). Data were collected by four different people. Interpretations of observations were standardized during training exercises every time an observer had not continuously collected data during the previous three week period.

Data Analysis

We selected variables that represent three important aspects of foraging by Chestnut-backs: (1) use of tree species, (2) foraging substrate, and (3) foraging mode. Chestnut-backs spent nearly 99% of the time foraging in six species of trees, using four different substrates and eight foraging modes (Brennan and Morrison, unpubl. data). For this study we used data that illustrate the variability of foraging by Chestnut-backs on two species of trees (Douglas-fir and white fir), in two substrates (tree foliage and tree twigs), and using two foraging modes (gleaning and hanging). We selected these variables because they represent aspects of foraging that are used in varying amounts during different seasons.

The raw data from each foraging observation were transformed into a matrix of percentages of the total time Chestnut-backs used each tree species, substrate, and foraging behavior. Transforming the data from a discrete (e.g., frequency of tree species use) to a continuous form (percent of observation time), by mathematically combining the frequency data with corresponding seconds of observation time, allowed us to analyze the data using standard one-way analysis of variance and associated tests for homogeneity of means and variances (see below). It also served to standardize the data because of the variation in observation time (8–30 s). Furthermore, this method allowed us to calculate confidence intervals around mean values. Incorporating sequential records of foraging behaviors into a single sample allowed us to circumvent problems of dependency that arise when each sequential record is treated as an individual sample.

We selected two-month intervals for our sample size analyses for several reasons. First, we needed sufficient samples to insure stability of means and variances. We considered estimates of means and variances to be stable when they converged with the estimates obtained from all (N = 80) samples used within a sampling period. The sample size of 80 was selected because this represented the largest number of samples collected during sampling periods in the fall and winter. Second, a two month period can be aligned with significant biological events during the chickadees' annual cycle: May through June is typically the core of the breeding period; family groups frequently forage as flocks during July and August; the onset of fall rains and leaf abscission for deciduous trees (most notably *Q. kelloggii*) occurs during September and October; the onset of winter and the first snows begin in the western Sierras during November and December; January and February are typically the coldest months; pre-breeding events (pair bonds and nest building) begin in March and April.

During each two month sampling period, we randomly subsampled (with replacement) each data set ten times, using sample size increments of ten. We used Student-Newman-Keuls multiple comparisons with one-way analysis of variance (Zar 1974:151) to test for differences in means of each different sample size for each variable.

For the statistical estimation of sample size, we used Stein's two-stage technique (Steel and Torrie 1960:86), which employs the following equation:

$$n = (t^2)(s^2)/(d^2)$$

where t is the t-value for the desired confidence interval with $n - 1$ degrees of freedom for the sample used, s is the standard deviation, and d is the half-width of the desired confidence interval. To be 95% confident that the mean of a given variable would be within 10% of the mean from all 80 samples from a particular sampling period, we sequentially calculated the standard deviations from 10, 20, 30 . . . n samples until the estimated sample size converged with the sample size of the subset being used. To analyze the effect of the length of sampling period on seasonal patterns of foraging we compared one month and two month sampling periods. This allowed us to examine seasonal patterns in relation to 6 and 12 intervals, each of which represents a different portion of the annual cycle.

RESULTS

Influence of Sample Size

Our data indicated that the size of the sample significantly affected the outcome of the analysis. At sample sizes >30, the estimated means appeared to converge with the mean value of a particular variable for the entire sampling period. Along with convergence of mean values, the standard deviations of the estimates also stabilized when 40 or more samples were used (Figs. 1–3).

Although the mean values varied widely between some sampling periods (see, for example the use of white fir [Figs. 1E,F], or the use of twigs [Figs. 2E,F]), time of year did not appear to affect the number of samples required for a stable estimate of means and variances.

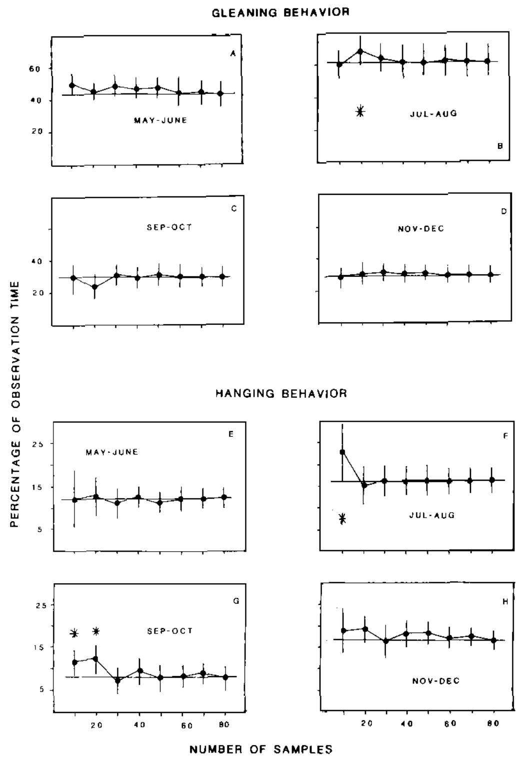

FIGURE 3. Percent time spent gleaning and hanging by Chestnut-backed Chickadees during four different sampling periods at Blodgett Forest Research Station, 1986-1987. Solid dots represent mean values at sample sizes ranging from 10 to 80 observations, vertical bars represent one standard deviation. Horizontal lines represent means calculated from all 80 samples. Asterisks denote means that were statistically different from the remaining homogeneous subset (P < 0.05 SNK-ANOVA).

In all cases involving variables and sampling periods, variances were not equal with different sample sizes (Bartlett's test for homogeneity of variances, P < 0.001). In four instances the mean values of the subsample estimates did not equal the other means from the subsamples of each variable (P < 0.05 Student-Newman-Keuls one-way analysis of variance [SNK-ANOVA]). These were: N = 10 for the May-June analysis of tree foliage use (Fig. 2A); N = 20 for the July–August analysis of gleaning behavior (Fig. 3B); N = 10 for the July–August analysis of hanging behavior (Fig. 3F) and N = 10–20 for the September–October analysis of hanging behavior (Fig. 3G).

TABLE 1. Sample Sizes Required for 95% Confidence That the Estimated Mean Is within 10% of the Mean Value, Calculated from the Entire Group of 80 Samples for Each Foraging Behavior Variable Using Chestnut-backed Chickadee Foraging Data Collected at Blodgett Forest, May–December 1986. Mean Values and Standard Deviations Used for the Sample Size Calculations Are Given in Figures 1–3

Sampling period	Variable	Size of sample used for calculation	Number of samples required[a]
May–June	Use of Douglas-fir	10	97
		20	30
	Use of white fir	10	91
		20	105
		30	36
	Use of tree foliage	10	17
	Use of tree twigs	10	203
		20	54
		30	30
	Gleaning behavior	10	10
	Hanging behavior	10	135
		20	59
		30	33
July–August	Use of Douglas-fir	10	204
		20	79
		30	70
		40	40
	Use of white fir	10	156
		20	25
	Use of tree foliage	10	85
		20	20
	Use of tree twigs	10	153
		20	25
	Gleaning behavior	10	10
	Hanging behavior	10	117
		20	33
September–October	Use of Douglas-fir	10	148
		20	126
		30	92
		40	73
		50	50
	Use of white fir	10	112
		20	48
	Use of tree foliage	10	22
	Use of tree twigs	10	40
		20	22
	Gleaning behavior	10	43
		20	20
	Hanging behavior	10	21
November–December	Use of Douglas fir	10	140
		20	41
	Use of white fir	10	305
		20	198
		30	57
		40	41
	Use of tree foliage	10	27
	Use of tree twigs	10	61
		20	21
	Gleaning behavior	10	22
		20	16

[a] Based on Stein's two-stage technique, see text for equation.

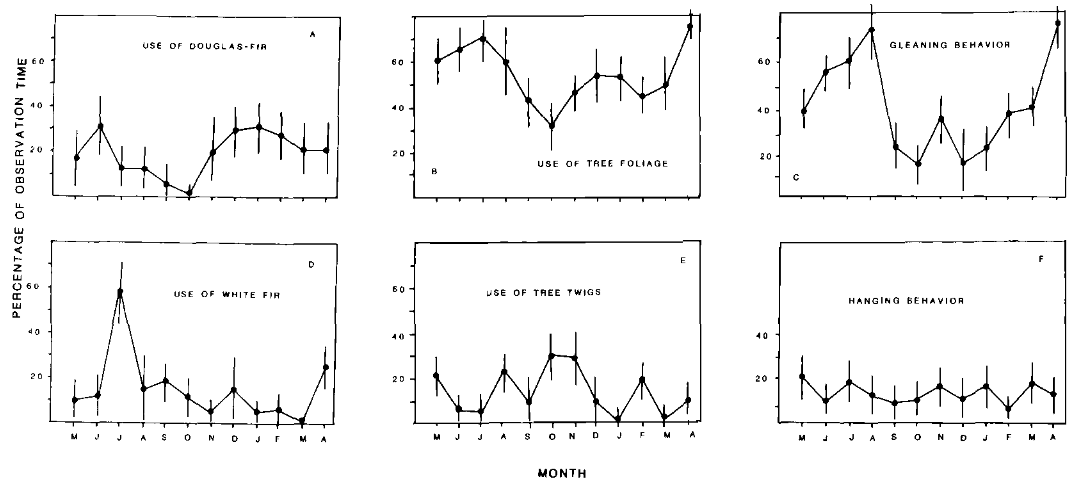

FIGURE 4. Seasonal variation in use of tree species, use of substrates, and foraging modes by Chestnut-backed Chickadees at Blodgett, using a one month interval. Dots represent mean values, vertical bars represent one standard deviation.

Otherwise, the means derived from subsampling 10–80 samples represented homogeneous groups of estimates that were not statistically different ($P < 0.05$; SNK-ANOVA).

Sample Size Estimation

The number of samples required to be within 10% of an estimated mean 95% of the time varied widely (Table 1). For example, common foraging behaviors, such as percent time foraging on foliage, or percent time gleaning from all substrates generally required 10–20 samples, whereas uncommon or highly variable behaviors such as use of white fir, use of Douglas-fir, or use of tree twigs required 30–50 samples (Table 1). In only one case were more than 40 samples required for estimating a variable: the use of Douglas-fir in September–October (Table 1).

Length of Sampling Period

We found similar patterns for both the one month and two month sampling periods (Figs. 4 and 5). The use of tree species, substrates, and foraging modes varied dramatically across the year in both analyses. For example, use of Douglas-fir decreased during the summer and then rose during late fall and early winter. Use of white fir increased dramatically during July and August, but was low during the rest of the year. The use of twigs increased and the use of foliage decreased during the fall (Figs. 4 and 5). Gleaning peaked during late summer, whereas time spent hanging from terminal buds, twigs, and foliage varied widely (Figs. 4 and 5).

DISCUSSION

Sample Size Analyses

The number of samples required to obtain reliable estimates of the relative amounts of time chickadees spend foraging was variable. Common behaviors typically required 10–20 samples for estimates of central tendency and dispersion, whereas less common behaviors required up to 40 (and in one case 50) samples. These results generally support Morrison's (1984a) findings that confidence intervals and mean values remained virtually unchanged at sample sizes ≥ 40 or larger; he concluded that samples from at least 30 individuals were required for a reliable estimate. We found, however, that some estimates based on 20 or fewer samples differed from the overall (all 80 samples) mean. These differences may be related to the different species studied: Morrison studied two species of migrant *Dendroica*, whereas we used a resident parid. Morrison collected data from April to July; thus, his results are most comparable with ours from May–June. None of the mean values calculated for the different sample sizes in our analyses was statistically different from the overall means for each variable during the May–June sampling period; perhaps there is less variation in behavior of foliage-gleaning birds during the breeding season than at other times of the year, and this accounted for the lack of statistical differences in the means for this sampling period.

Our estimates of the number of samples required for a reliable estimate of foraging behavior were considerably lower than those calculated by Petit et al. (this volume), who found that sev-

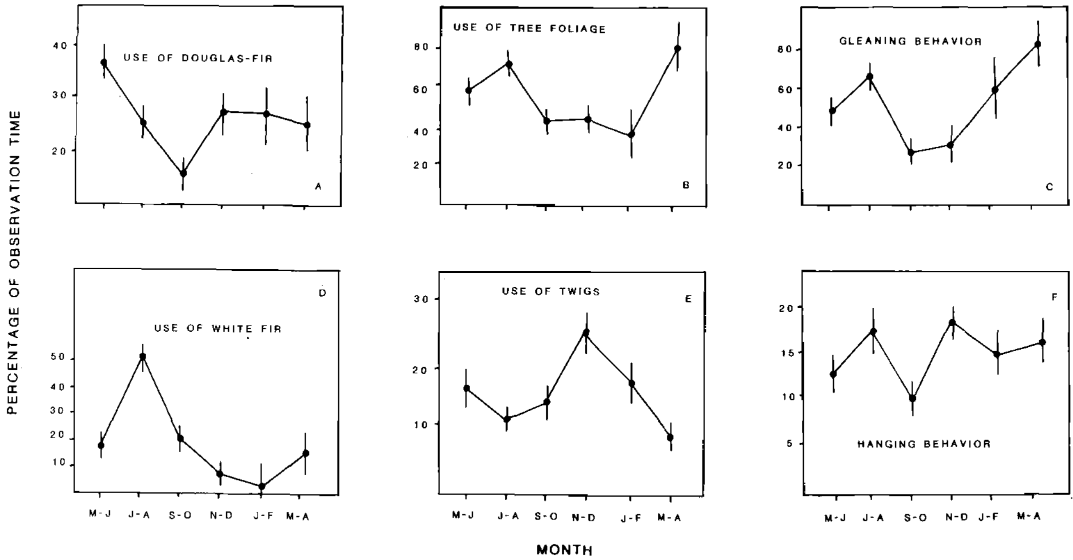

FIGURE 5. Seasonal variation in use of tree species, use of substrates, and foraging modes by Chestnut-backed Chickadees at Blodgett, using a two month interval. Dots represent mean values, vertical bars represent one standard deviation.

eral hundred samples were generally needed. The differences are most likely a function of analytical approaches. We used individual variables, whereas Petit et al. considered sets of foraging behavior categories simultaneously. As a result, behaviors used less than 5% of the time strongly influenced their calculations of sample sizes.

Influence of Sampling Time Scale

Although the one month and two month sampling periods showed similar seasonal foraging patterns, much detail was lost as the length of sampling period increased. Whether this is important depends on the questions being asked. For example, an assessment of interactions between a population of birds and changes in food availability would require numerous, short sampling periods, whereas a general assessment of foraging behavior could be done using longer (2–3 month) sampling intervals. The inherent variability and shifts in foraging behavior are "smoothed out" as the time interval is increased.

Chickadees are, in many respects, generalists with a wide repertoire of foraging behaviors. Our results indicated that reliable estimates of their foraging behavior require at least 40–50 behavior samples per sampling period. Year-round analysis would require a minimum of 240–480 samples, depending on sampling interval (two months vs. one month). For a year-round investigation of an assemblage of, say, ten species, a minimum of 2400 behavior samples would be required, depending on the behavioral variability of individual species. Species with less varied behavior would probably require fewer samples. There is no sound biological or statistical justification for attempting such community-level analyses if adequate numbers of samples cannot be collected; even cursory survey work would be suspect. Thus, researchers would be advised to restrict their sampling to the number of species for which adequate samples—and thus meaningful results—can be obtained. In all cases sample size analysis is essential.

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