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# INFLUENCE OF SAMPLE SIZE AND SAMPLING DESIGN ON ANALYSIS OF AVIAN FORAGING BEHAVIOR

MICHAEL L. MORRISON

ABSTRACT.—I analyzed the influence of sampling scheme and sample size on results of foraging behavior of the Hermit (*Dendroica occidentalis*) and Black-throated Gray (*D. nigrescens*) warblers using both single point and sequential observational methods. Single point observations gave results similar to those of sequential observations except for the use of foraging heights and species of tree; infrequently used heights and tree species were not detected by the single point method. Making sequential observations apparently allows an observer to follow an individual bird through a wider range of activities (e.g., use of low heights) as compared to single point observations. Results indicate that at least 30 individuals constitute the minimum sample necessary to analyze foraging behavior. Statistical problems associated with the sequential observation method are discussed, as are suggestions for alternative methods of sampling foraging behavior.

Although much contemporary ecological theory is based on foraging behavior, virtually no attention has been given to evaluations of the techniques used or the effects of sample size on the quantification of avian foraging behavior. The number of papers using foraging behavior as the base for models of coexistence among bird species has proliferated since MacArthur's (1958) classic paper. Although several authors have expressed concern (e.g., Sturman 1968, Hertz et al. 1976), I have found only one study specifically designed to evaluate the influence of sampling procedures on results of foraging behavior of birds—Wagner (1981) found that the method of recording data has an effect on results. She advised caution when comparing results between species of birds and between studies, but did not assess the effect of sample size on her results. Holmes et al. (1979) noted that analysis of foraging data in subsets (i.e., first observations only) did not differ from analyses of all observations recorded in sequence. They did not, however, give either details of their analyses or the effects of sample size on their results.

I designed this study to expand upon Wagner (1981) by analyzing the influence of sampling design and sample size on results of foraging behavior using two common methods of data collection and analysis. The Hermit (*Dendroica occidentalis*) and Black-throated Gray (*D. nigrescens*) warblers were used as subjects.

## METHODS

I studied the foraging behavior of male Hermit and Black-throated Gray warblers in a mature Douglas-fir (*Pseudotsuga menziesii*)–Oregon white oak (*Quercus garryana*) forest in and around the Finley National Wildlife Refuge, Benton Co., Oregon, from April to July of 1980 and 1981. The study area was described in Morrison (1982). Data recorded for each foraging individual were foraging height, height and type of foraging substrate, and foraging mode (gleaning, hover-gleaning, or flycatching). Data were recorded at 60-s intervals for a total of five observations of each individual encountered; shorter sequences of observations were excluded from analysis and birds could seldom be observed for longer than 5 min in this habitat. Foraging heights were later categorized by height intervals (0.0–4.0, 4.1–10.0, 10.1–20.0, 20.1–30.0, >30.0 m).

I analyzed the influence of sampling scheme on results of foraging behavior by assessing the difference between two commonly used observational techniques: (1) single point observations (i.e., using only the first sighting of an individual); and (2) sequential observations (i.e., using observations 1–5) of a single individual. These correspond to Method 1 and Method 2, respectively, of Wagner (1981). The influence of sample size on results of foraging behavior was determined by varying the number of observations obtained by each method. Data were first analyzed in the order in which they were collected in the field. To calculate confidence intervals around each subsample mean, I next randomly selected three subsets of data for each subsample for both methods. Confidence intervals were used to assess the stability of means of foraging parameters.

## RESULTS

### INFLUENCE OF SAMPLE SIZE

*Point observations (Method 1).* Heights of foraging substrates did not stabilize (i.e., small change in means, narrow confidence intervals) until $n = 30$ for the Hermit Warbler (Fig. 1).

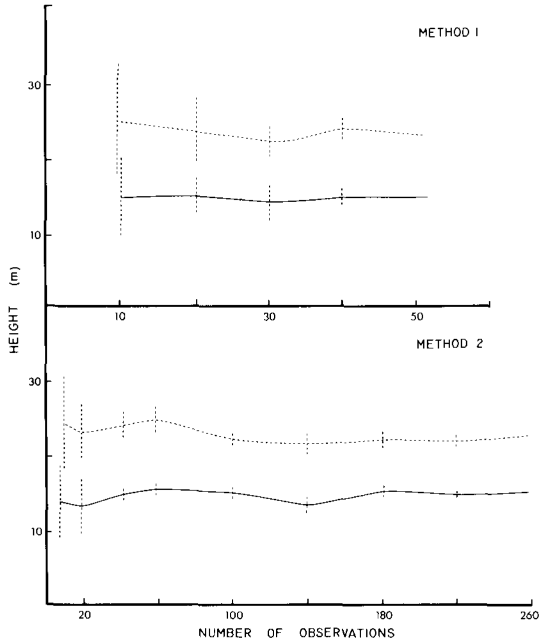


FIGURE 1. Substrate (dashed lines) and foraging (solid lines) heights for Hermit Warblers derived from single point (Method 1) and sequential (Method 2) observations. Dashed vertical lines are 95% confidence intervals.

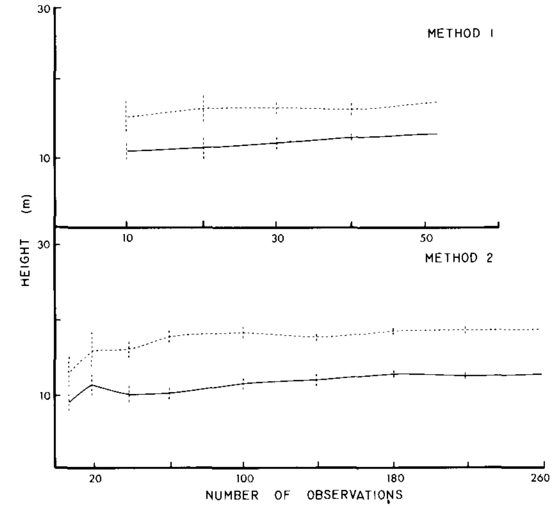


FIGURE 2. Substrate (dashed lines) and foraging (solid lines) heights for Black-throated Gray Warblers derived from single point (Method 1) and sequential (Method 2) observations. Dashed vertical lines are 95% confidence intervals.

These parameters were stable for all sample sizes ($n$) for the Black-throated Gray Warbler (Fig. 2).

Means for all foraging modes for the Hermit Warbler changed for all $n$'s, although confidence intervals narrowed at $n = 40$ (Fig. 3). Means for foraging modes of Black-throated Gray Warblers remained roughly unchanged after $n = 40$; confidence intervals also narrowed at $n = 40$ (Fig. 4). All foraging modes for both species were used at the maximum $n$ (i.e., total sample collected for this study). Flycatching did not appear in the sample until $n = 40$ for the Black-throated Gray Warbler. For the Hermit Warbler, hover-gleaning and flycatching did not appear until $n = 40$.

The tree species used for foraging changed at all $n$'s for the Hermit Warbler; confidence intervals narrowed for each consecutive $n$, becoming small at $n = 40$ (Fig. 5). Means for the use of foraging substrates by Black-throated Gray Warblers appeared to stabilize at $n = 40$; however, confidence intervals for use of Douglas-fir and white oak increased slightly between $n = 30$ and $n = 40$ (Fig. 6). Douglas-fir appeared at all $n$'s for the Hermit Warbler; western hemlock (*Tsuga heterophylla*) first appeared at $n = 30$ and oak appeared only at maximum $n$. Douglas-fir and hemlock were used at all $n$'s by the Black-throated Gray Warbler; oak first appeared at $n = 20$.

*Sequential observations (Method 2).* Means of foraging and heights of substrate were stable at $n = 60$ for both species except (1) the use of substrate height for Hermit Warbler, which stabilized at $n = 100$ and (2) the foraging height

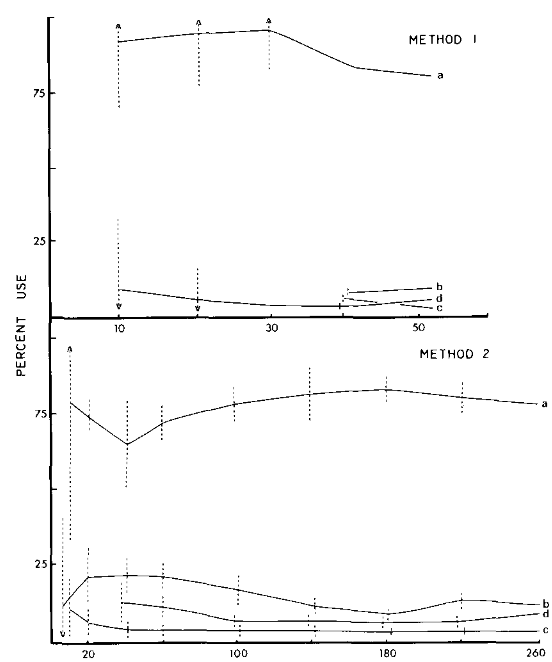


FIGURE 3. Foraging modes for Hermit Warblers derived from single point (Method 1) and sequential (Method 2) observations. Foraging modes: a = gleaning; b = hover-gleaning; c = flycatching; d = other. Dashed vertical lines are 95% confidence intervals.

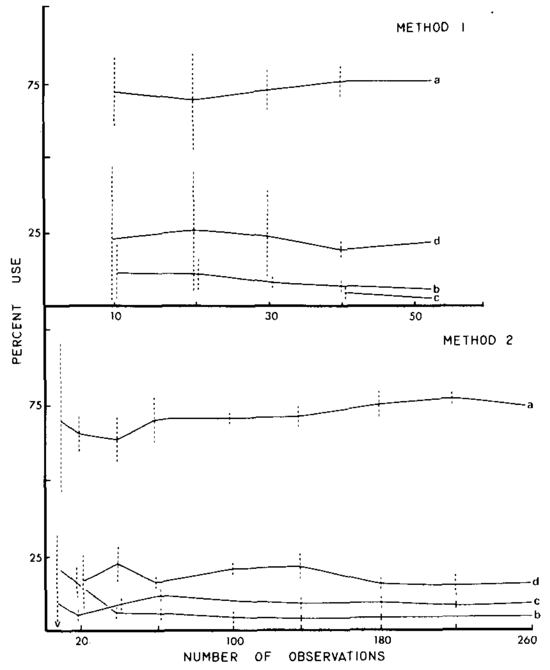


FIGURE 4. Foraging modes for Black-throated Gray Warblers derived from single point (Method 1) and sequential (Method 2) observations. Foraging modes: a = gleaning; b = hover-gleaning; c = flycatching; d = other. Dashed vertical lines are 95% confidence intervals.

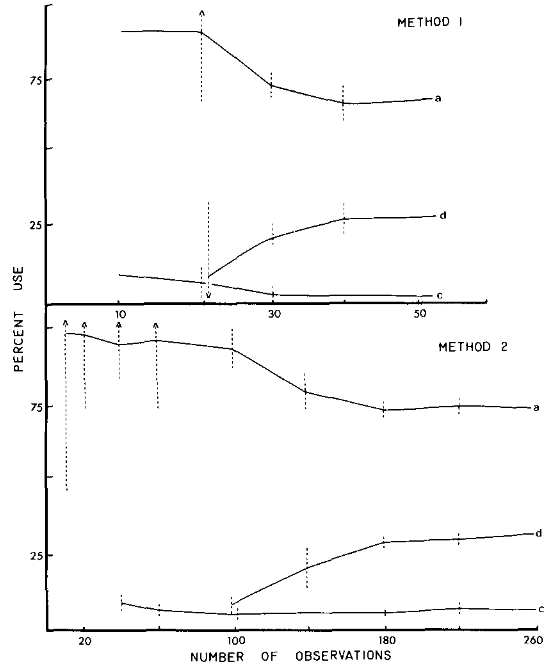


FIGURE 6. Tree species used for foraging by Black-throated Gray Warblers derived from single point (Method 1) and sequential (Method 2) observations. Tree species: a = Douglas-fir; b = red alder; c = western hemlock; d = white oak; e = other. Dashed vertical lines are 95% confidence intervals.

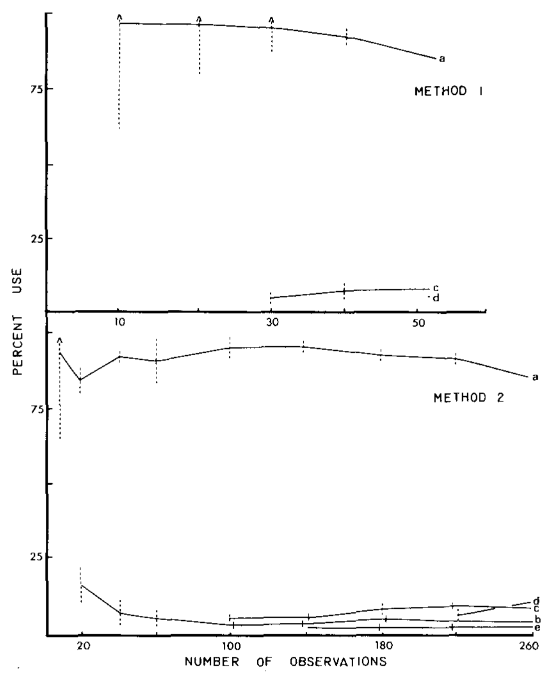


FIGURE 5. Tree species used for foraging by Hermit Warblers derived from single point (Method 1) and sequential (Method 2) observations. Tree species: a = Douglas-fir; b = red alder; c = western hemlock; d = white oak; e = other. Dashed vertical lines are 95% confidence intervals.

of the Black-throated Gray Warbler, the means of which slowly increased at $n > 40$ until stabilizing at $n = 180$ (Figs. 1 and 2).

Foraging mode stabilized at $n > 100$ for both species (Figs. 3 and 4). All foraging modes were used by $n = 20$ for the Black-throated Gray Warbler and $n = 40$ for the Hermit Warbler.

The tree species used for foraging stabilized at $n = 60$ for the Hermit Warbler, although the use of minor substrates increased slightly for all $n$'s (Fig. 5). Substrate use changed markedly for the Black-throated Gray Warbler until stabilizing at $n = 180$ (Fig. 6). All species of substrates were used at maximum $n$ by the Hermit Warbler. Only Douglas-fir and red alder (*Alnus rubra*) appeared through $n = 100$; western hemlock and various rare substrates were added by $n = 140$ and white oak appeared at $n = 200$. Only Douglas-fir, hemlock and oak were used by the Black-throated Gray Warbler; oak did not appear until $n = 100$.

## COMPARISON OF SAMPLING METHODS

Both sampling methods gave virtually identical results for most analyses of foraging behavior at maximum $n$ (Table 1). Method 1 indicated a lower frequency of hover-gleaning than Method 2 for the Black-throated Gray Warbler. The use of red alder and various oth-

TABLE 1. Summary of foraging behavior of male Hermit and Black-throated Gray warblers for the two methods of analysis at the maximum sample size used in this study.[a]

| | Hermit Warbler | | Black-throated Gray Warbler | |
|---|---|---|---|---|
| | Method 1 | Method 2 | Method 1 | Method 2 |
| Foraging height (m) | 14.7 (4.62) | 14.7 (4.66) | 12.5 (3.53) | 12.4 (4.25) |
| Substrate height (m) | 22.0 (6.57) | 22.0 (7.13) | 17.3 (4.77) | 17.4 (5.05) |
| Foraging mode (%) | | | | |
| Gleaning | 78.8 | 77.7 | 75.0 | 73.1 |
| Hover-gleaning | 11.5 | 11.2 | 3.8 | 10.0 |
| Flycatching | 3.8 | 1.9 | 1.9 | 2.7 |
| Other | 5.8 | 9.2 | 19.2 | 14.2 |
| Species of substrate (%) | | | | |
| Douglas-fir | 84.6 | 86.5 | 69.2 | 70.8 |
| Red alder | 0.0 | 1.2 | 0.0 | 0.0 |
| Western hemlock | 7.7 | 5.4 | 1.9 | 1.5 |
| White oak | 7.7 | 6.5 | 28.8 | 27.7 |
| Other | 0.0 | 0.4 | 0.0 | 0.0 |
| Height intervals (%) | | | | |
| 0.0–4.0 m | 0.0 | 0.4 | 0.0 | 3.1 |
| 4.1–10.0 | 17.3 | 18.5 | 26.9 | 26.9 |
| 10.1–20.0 | 75.0 | 73.1 | 71.2 | 66.9 |
| 20.1–30.0 | 5.8 | 6.9 | 1.9 | 3.1 |
| >30.0 m | 1.9 | 1.2 | 0.0 | 0.0 |

[a] Sample size: Method 1 = 60 observations; Method 2 = 260 observations.

er plants (mostly shrubs; the "other" category) was missed by Method 1 but appeared in the results for Method 2 for the Hermit Warbler; the use of vegetation was the same for the Black-throated Gray Warbler by both methods. The use of vegetation by height intervals was similar for both methods except that the lowest interval did not appear in Method 1 for both bird species.

## DISCUSSION

Single point observations (Method 1) of foraging behavior gave virtually the same results as sequential observations (Method 2) for all analyses except the use of height intervals and species of tree. The lower height intervals were missed during Method 1, likely a reflection of the conspicuousness of the birds. That is, an observer notices singing males, who sing mostly in the upper portions of trees. With Method 2, one initially notices singing birds but can then follow the bird through a wider range of activities.

Although the use of substrates appeared to be similar for both methods for the Black-throated Gray Warbler, substrate use differed between methods for the Hermit Warbler. As noted for use of height intervals, Method 2 apparently gave a more thorough indication of substrate use than Method 1 (at least through the $n$'s used in this study).

Thus, Method 1 will probably give an incomplete assessment of relatively rare foraging behaviors unless both singing and non-singing birds are sampled. Recording data only on non-singing individuals (including females) would reduce the apparent bias introduced into data by recording only singing males (e.g., Sturman 1968, Altmann 1974, Hertz et al. 1976). Gathering data only on non-singing birds, however, is difficult and time-consuming in most species of birds. In addition, ignoring singing individuals eliminates identification of possibly important aspects of the habitat requirements of a species (e.g., perch sites). A compromise between sampling solely by Method 1 or 2 might be to record all non-singers, but only every second or third (for example) singer encountered (J. Verner, pers. comm.); such a compromise method deserves study.

I agree with Hertz et al. (1976) and Wagner (1981) that the preferred method of sampling foraging behavior for (at least) passerine birds is continuous recording (Method 2) of a large number of individuals because it more completely reveals rare behaviors than point observations (Method 1). A problem with statistical analysis of data generated from Method 2, however, is that sequential observations of an individual bird are not independent; that is, each sequential observation is usually correlated with previous observations. It is thus essential that a large sample of foraging observations from numerous individuals be included in analysis of foraging behavior. My results indicate that at least 30 individuals (about 150 sequential observations) constitute a minimum sample required for analysis of foraging behavior. Further studies are needed to determine if these minimum (stabilized) samples are widely applicable.

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*Department of Forestry and Resource Management, University of California, Berkeley, California 94720.* Received 11 February 1983. Final acceptance 2 September 1983.

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# RECENT PUBLICATIONS

**Vulture Biology and Management.**—Edited by Sanford R. Wilbur and Jerome A. Jackson. 1983. University of California Press, Berkeley. 552 p. $35.00. Sparked by concern for the decline of several species of Old World and New World vultures, an International Symposium on the Vultures was held in 1979. This book presents a number of papers from that meeting, plus others that were invited in order to provide a more comprehensive picture of these birds. They are grouped topically as follows: paleontology and systematics, status of species according to region, biology of OW and NW vultures, research and management techniques, effects of environmental contaminants, and human relationships with vultures. The final part is a bibliography of the vultures, supplementing the lists of references at the ends of the papers. This volume outlines most of our present knowledge about vultures, and will therefore be an important reference for anyone who works with them. Ecologists too, might find it worthwhile to give more thought to the role(s) of these scavengers in terrestrial ecosystems. Illustrations, indexes.

**Working Bibliography of the Golden Eagle and the Genus *Aquila*.**—Maurice N. LeFranc, Jr., and William S. Clark. 1983. Scientific & Technical Series No. 7, National Wildlife Federation, Washington, DC 264 p. Paper cover. Source: Raptor Information Center, N.W.F., 1412 16th St., N.W., Washington, DC 20036. Eagles are acclaimed as inspiring birds, so it is no wonder that they have inspired more bibliographies than other species. The present one covers a different subject than that by Lincer, Clark, and LeFranc, Jr. (noticed in The Condor 81:257) and it overlaps only in small part with those by Knight (The Condor 82:290) and Allen, Knight, and Stalmaster (The Condor 83:91). Its Foreword by the late Leslie Brown is followed by introductions to the bibliography itself and to the nine or ten species in the genus *Aquila*. The master list then presents more than 3,400 citations culled from North American and major foreign journals up through September 1982. This can be entered by way of a permuted list of keywords (aided by a glossary in the appendix), or by species and geographic indexes. Finally there is a list of citations of occurrences of the Golden Eagle in North America, arranged by provinces and states. This book will certainly be a useful reference for researchers and biologists responsible for managing *Aquila* eagles. A casual check by this reviewer, however, disclosed the omission of several non-obscure references, a reminder to exercise caution in trusting bibliographies to be complete.