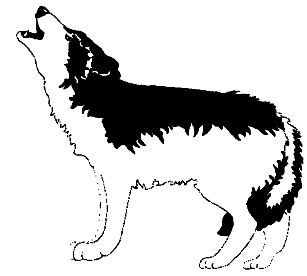
In My Opinion



The need to get the basics right in wildlife field studies

David R. Anderson

Theoretical and applied ecology represent large and complex disciplines, and it is easy to get lost in the details, particularly the analytical details. However, if data are collected in ways that are fundamentally flawed, no analysis theory will allow valid inferences about populations of interest. Research and management objectives are sacrificed when the collection of data is seriously flawed, as noted in Romesburg's papers on "reliable information" (Romesburg 1981, 1989, 1991, 1993). My objective is to focus attention on 2 major problems that seem fundamental to much of what we do in wildlife field studies: 1) the frequent use of convenience sampling and 2) the use of index values (usually raw counts) purporting to measure "relative abundance." These problems result in a lack of rigor and validity in research and in management decision-making (White 2001).

Convenience sampling

Ecological data are often taken using what is termed convenience or subjective sampling. Here data are collected along roads, trails, or utility corridors and hence are not "representative" of the population of interest. Other examples of convenience sampling include data taken subjectively near camp, around parking areas, or on areas where density is known to be high. Biologists often use convenience sampling in their field work because it is easier (e.g., drive down a road and stop occasionally to record numbers). Using numbers from convenience sampling, one can make only weak statements about some feature of the sample itself (e.g., animal abundance near roads or population density in areas where density is high) rather than a formal inductive inference concerning the population of interest. If one is interested in making an inference concerning some aspect of adult people in Colorado, it is nonsensical, but perhaps convenient, to sample deer hunters or priests or lawyers as a basis for inference to the more general, defined population (Williams 1978).

The proper approach is understood by most biologists: select sample units in a probabilistic manner—a procedure in which subjectivity and convenience are replaced by some type of random selection (Yates 1949, Deming 1950, Kish 1965, Bellhouse 1988, Hayek and Buzas 1997). Probabilistic sampling is not haphazard; it is a defined process with a rigorous meaning. Probabilistic sampling includes simple random, cluster, double, adaptive sampling, various stratified random designs (see Cochran 1963 and Thompson 1992 for an overview of standard methods, while Slonim 1960 provides a simple introduction to the principles). While most biologists understand these fundamentals, some managers do not comprehend the deep level of importance of proper probabilistic sampling (Stuart 1984). Perhaps research and management biologists fail to realize how untrustworthy inferences from subjective, convenience samples can be.

Two substantial problems result from the common use of convenience sampling: 1) there is no valid basis for an inductive inference from the

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sample data to the population of interest and 2) there is no valid basis to assess precision of population parameters that have been estimated. There is a large literature on inferential problems when using nonrandom sampling designs (e.g., Williams 1978, Edwards 1998).

Rosenstock et al. (2002) sampled 224 papers in 9 ornithological journals and one conference proceeding, covering the period 1989–1998, to estimate prevalence of convenience sampling versus probabilistic sampling in avian field studies. They found that only 14% of the papers used some type of probability-based sampling protocol. Most authors merely used some type of convenience sampling, most often involving existing roads or trails; this is poor practice, for the 2 reasons given. Hopefully, no academic program advocates convenience sampling, however many people use this poor approach in their field studies.

Index values

While common sense might suggest that one should estimate parameters of interest (e.g., population density or abundance), many investigators have settled for only a crude index value (e.g.,"relative abundance"), usually a raw count. Conceptually, such an index value (c) is the product of the parameter of interest (N) and a detection or encounter probability (p): then $c=pN$ (see Lancia et al. 1994; Nichols et al. 1998*a*, *b*).

Index methodology rests on critical and unrealistic assumptions concerning the detection probability (p). The main assumption is the loose notion that the count (c) is an index of "relative abundance" and that such an index is rated closely to true abundance, across habitat types, observers, and other factors (see Gibbs 2000). That is, the count is blindly assumed to be a close surrogate for population size or density. Put another way, it must be assumed that the detection probability (p) is constant across habitat types, observers, and other factors; this assumption seems absurd. There is often an admission that the index might be only weakly related to the size of the population sampled, but then investigators proceed as if the index was indeed a variable related closely to population size or density.

There are 3 classes of variables that affect the probability of detection and therefore the index, in addition to true abundance (Buckland et al. 1993). First are variables related to the observer, or perhaps several observers used during a multi-year survey. These variables include the observer's training and education, experience, interest, hearing ability, eyesight, height, and fatigue level. Each of these variables can affect the probability of detection and therefore have substantial effects on the index (e.g., see Bart and Schoultz 1984). Second are variables associated with the environment that have substantial effects on number detected and counted (the index). These include wind speed, temperature, precipitation, time of sunrise, habitat type, season of year and its phenology, vegetation height and density, human disturbance, cloud cover, and a host of others. The third class of variables includes aspects of the species itself that affect its detectability—e.g., coloration, behavior, gender, flock size, calling intensity and rate, and matedness (e.g., Baskett 1993).

Many of the variables that affect detectability, and therefore the count, exhibit time trends, further confounding the value and interpretation of the index. Such time trends are often correlated with the observer's age, successional changes in vegetation height and density, or human-caused disturbance (e.g., increase in number of buildings near roads). Time trends in such variables have a direct effect on the magnitude of the count (index). One may find a clear decrease in the count or index over 15 years, but this is hardly evidence that the population declined. Perhaps only detectability declined due to increasing cover (e.g., increasing forest height and density), while the population size remained somewhat constant or actually increased. Habitat and observer variables affecting detection probability confound the assessment of species status for potential listing or recovery under the Endangered Species Act.

The "index" is partially a function of abundance (the variable of interest), but also is a function of a long list of variables associated with the observer, the environment, and characteristics of the species being surveyed, and these change over years. Even if the sampling design was done properly, inference based on such an index cannot be expected to yield what Romesburg (1981, 1991) terms "reliable information." The use of index values seems not just poor but actually unprofessional.

Only 41% of the papers reviewed by Rosenstock et al. (2002) had any measure of precision associated with the index value (in fact, most of the estimates of precision given were incorrect because the data used were from convenience sampling).

Perhaps there is a place for index values as explanatory (predictor) variables, but not as a response variable. Eberhardt and Thomas (1991) review these issues with an emphasis on experimentation, and Eberhardt and Simmons (1987) review the use of double sampling in calibrating index values. Double sampling has been used in many biological fields for decades to provide a rigorous means of making valid estimates of population parameters based on empirical relationships between index values and estimates of actual parameter values (Yates 1949, Cochran 1963, Kish 1965). Relatively few surveys use standard double sampling methods to calibrate the raw index values into parameter estimates and obtain valid estimates of precision (but see Estes and Jameson 1988 for a nice example).

Summary

Many investigators begin field studies by using convenience sampling and then collect only index values (i.e., raw counts). This combination of poor field practices is nearly certain to yield untrustworthy results. Numbers (i.e., index values) are not always data, and many numbers (large sample size) do not always mean good data. Instead, the word data implies an information content with respect to some objective. Often numbers can be collected, but they may not represent data because they have little meaning and cannot be interpreted without making critical, but very unrealistic, assumptions. Such numbers are not trustworthy and cannot lead to valid inferences about the population of interest.

We have made serious errors in *ad hoc* surveys of many terrestrial populations; efforts are underway to try to alter survey protocol to lessen these deficiencies in some cases. However, new surveys are being planned for reptile, amphibian, and insect populations, and the same fundamental errors may be repeated. Convenience samples are being relied upon without a way to make valid inferences about populations of interest. Index values are being taken without regard for highly variable and perhaps time-trending detection probabilities. Numbers from such surveys will not provide a basis for reliable knowledge and will represent only wasted resources. We must improve our understanding of these 2 fundamental issues and obtain reliable information or professionals in other disciplines will not take us seriously.

Delury (1954: 293) commented, "...it is an expensive impropriety to maintain that an untrustworthy estimate is better than none." Professors ought to instill in their students the importance of probabilistic sampling in field studies. Similarly, the use of index values ought to be discouraged strongly because alternatives exist that will provide, under given assumptions, meaningful parameter estimates, measures of their precision, and other forms of reliable information (see Thompson et al. 1998, Seber and Schwarz 1999).

Editors and referees must begin to ask whether the sample data were taken in such a way as to allow a formal inductive inference to the population of interest. Such information should appear clearly in the *Methods* section of papers submitted for publication. Data resulting from convenience sampling are not acceptable on fundamental grounds. Similarly, raw counts as index values are not reliable and should be published only in unusual circumstances. In my opinion, we need a much higher standard for what is intrinsically acceptable in our profession.

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