WILDLIFE TOXICOLOGY and POPULATION MODELING

Integrated Studies of Agroecosystems

Edited by

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Experimental Design, Statistical Analysis, and Demographic Models

Michael R. Willig

ABSTRACT

The detection of individual and population-level responses of wildlife to exposure to biocides frequently requires a quantitative approach during the design and analysis stages of experimentation. Limited familiarity with a particular arsenal of statistical tools or models often constrains experimental design and compromises subsequent analytical options. Exposure to a broader spectrum of approaches and designs, as summarized hereafter, may provide the impetus to restructure experimental protocols in a fashion that may more appropriately define the quantitative responses by wildlife to biocides in either a laboratory or field setting.

INTRODUCTION

Like environmental sciences in general, the field of avian wildlife toxicology is increasingly characterized by experiments that require a variety of different types of quantitative analyses. Perhaps the most difficult task that a scientist faces after deciding which questions to address[1] comprises the design of experiments that are feasible to conduct and likely to provide data capable of falsifying hypotheses. In many situations, knowledge of available statistical procedures and their limitations is among the more important factors guiding experimental design. Nothing is more frustrating to the environmental scientist or to the biostatistician than to discover that an elaborate, time consuming, and costly set of experiments cannot be analyzed in a very powerful fashion because adequate statistical advice was not sought prior to the collection of data. In a recent review of experiences as an editor for *Ecology*, Fowler[2] enumerated ten common statistical errors in ecological research and remarked that "over half of the papers that involved a statistical analysis had one or more errors" and "many of these errors involved relatively basic statistical knowledge." In many such cases, triage is unfortunately all that can be accomplished with the data, and discrimination among competing hypotheses remains as a task for future investigation. The chapters within this section provide both a general overview and a modicum of advice to those interested in the experimental design and analysis of data relevant to avian wildlife toxicology. The chapters by Dixon and Garrett[3] and Lacher and Willig[4] consider issues in univariate and multivariate data analysis, whereas the subsequent chapters by Skalski and Smith[5] and Sauer et al.[6] provide statistical interfaces to modeling demographic processes in wildlife populations.

EXPERIMENTAL DESIGN AND STATISTICAL ANALYSIS

No attempt has been made to be broadly inclusive of the entire field of biometry, in part because a number of excellent intermediate and advanced texts already do so.[7-15] Rather, the intent of the contributions by Dixon and Garrett[3] and Lacher and Willig[4] is to review and develop, within the context of ecotoxicological studies, a selection of useful statistical approaches and points of view concerning experimental design.

Dixon and Garrett[3] review the interrelated concepts of inference space, pseudoreplication, and statistical power as they apply to field experiments. This nicely sets the stage for a more detailed elucidation of the theory and application of bioequivalence tests: statistical procedures that directly evaluate if a particular treatment has no effect. Although bioequivalence procedures have not received widespread coverage in ecological and wildlife literature, they show much promise in applications concerning the detection of analytes and the effects of biocides on wildlife.

The chapter by Lacher and Willig[4] focuses on a variety of topics in multivariate statistics of interest to the wildlife toxicologists. In particular, many questions concerning the effects of biocides on fitness components or reproduction are inherently multifaceted in nature, and thus appropriately analyzed by multivariable procedures. In addition to reviewing the use of multivariate analysis of variance, principal components analysis, and discriminant analysis, they provide a protocol that may be useful in the analysis of multivariable data, one which avoids Rao's paradox and identifies the contributions of particular variables to multivariate differences.

DEMOGRAPHIC INTERFACES

Quantitative demographic models are of heuristic and predictive value to those interested in questions concerning avian wildlife toxicology. Demographic models can aid in answering questions, as well as in formulating them. To this end, estimating population parameters from field data is an important step in demographic modeling.

Sauer et al.[6] detail statistical issues relevant to modeling demographic trends by focusing on the rate of population increase and sources of its variation. Distinction between chronic and acute effects of biocides and the use of statistical approaches to evaluate the existence and significance of changepoints (alterations in population trajectories) in avian populations are particularly noteworthy contributions. The effect of a stressor (in their example, severe winters rather than biocide applications) on Eastern bluebirds provides a concrete example of the kind of applications that trend analysis can contribute to the field of avian wildlife toxicology.

Finally, the contribution by Skalski and Smith[5] focuses on risk assessment to avian populations from biocides by elaborating two approaches based upon mean temporal abundance. The direct quantification approach, based upon replication of control and treatment conditions, as well as randomization, constitutes the "notochord" of an effective experimental design, whether considering single or multiple year censuses. Demographic models offer the advantage of identifying the components of fitness (fecundity and survivorship) and incorporating their interaction with the environment and biocides. The theory and application of such procedures to field studies based upon radiotelemetry and mark-recapture are considered in detail. Finally, epidemiological approaches to statistical analysis, which are based upon individual birds rather than study plots as replicates, provide a powerful tool for detecting the effects of biocides on wildlife demography.

Together, these four contributions[3-6] provide a glimpse of the opportunities available to the avian wildlife toxicologist. The design of experiments and the selection of subsequent analyses are really different faces of the same coin. A well-designed study is able to clearly define the question, place it in the context of contemporary science, and produce data amenable to quantitative analysis. It is our hope that the following four contributions will hasten that process.

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