Ethology **109,** 781—784 (2003)

ISSN 0179–1613

Book Reviews

Quinn, G. P. & **Keough**, M. J. 2002: Experimental Designs and Data Analysis for Biologists. Cambridge University Press, Cambridge. 537 pp., Hardback: £75.00. ISBN 0-521-81128-7; Paperback: £29.95. ISBN 0-521-00976-6.

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When scanning through the commonly used statistical textbooks one may recognize that there is much overlap between them. For instance, most books comprise detailed descriptions of more or less the same set of non-parametric tests. Similarly, many forms of ANOVA are thoroughly treated in most titles. However, important aspects of several tests (e.g. the implications of unbalanced data in factorial ANOVA) are somewhat hidden in between pages and pages of explanations, formulas, and examples, and seemingly are not very accessible to many readers. In addition, important procedures like Principal Components Analysis (PCA), General or Generalized Linear Models (GLM), or Discriminant Function Analysis (DFA; to mention just a few) that are now commonly used in behavioural research and are also included in most of the popular statistical software packages have rarely found their way into those popular textbooks.

It thus was a pleasant surprise to see that Quinn and Keough largely refrained from indicating all the formulas and descriptions that are already included in so many textbooks (in fact, they also did not include a single table of critical values of test statistics). Instead, they took a rather new approach in that they put a clear focus on the assumptions and critical aspects of various procedures and the implications they have for practical research.

For instance, the four chapters about several variants of ANOVA include very detailed and intelligible discussions about fixed and random effect factors and the consequences corresponding decisions have for the interpretation of results obtained. Similarly, interactions and the consequences of unbalanced data in factorial data sets are at least partly treated rather thoroughly. I hardly ever read such clear accounts about these important although puzzling topics and their implications. In addition, the authors put much effort into explaining assumptions, and possible checks as to whether these hold. By the way, Quinn and Keough also provide a very clearly defined terminology with regard to the different variants of factorial designs, clarify the often confused terms 'replicate' and 'repeated' measures, and point out the relationship between 'multifactor', 'randomized complete blocks', and 'repeated measures' ANOVA. These terms sometimes seem to cause misunderstandings among ethologists. Given that analysing factorial data sets by means of linear models has become increasingly popular in animal behaviour research, I assume that many readers, authors, and referees of scientific journals will much appreciate these clear and comprehensive accounts.

Other chapters cover, for example, simple and multiple regression, ANOVA, GLM, MANOVA, DFA, PCA, and cluster analyses. Although the chapters about multivariate procedures are less extensive than the chapters about univariate analyses, they still will be of much interest and practical use for many researchers. Further chapters give introductions to parameter estimation and hypothesis testing, graphical exploration of data and presentation of results. Particularly noteworthy are a paragraph introducing the idea of bayesian inference, and a brief but very interesting overview about the 'Critique of statistical hypothesis testing'.

A particularly important chapter deals with 'Design and power analysis'. This chapter explains, for example, the idea of 'independence of data' and treats 'confounding variables' and 'pseudo-replication' in great detail. A chapter dealing with these topics is clearly missing in each statistics book I am aware of, probably because authors usually assume that these very basic issues do not require a separate chapter but are sufficiently covered by their book in general. However, it is my personal impression that these issues are still a matter of considerable misunderstanding among behaviourists. Perhaps this chapter could contribute a lot to their clarification. In addition, it is very nicely and clearly written and I found it very pleasant and partly even amusing (in a positive sense), something that probably rarely happens to readers of statistics books.

Chapters throughout the book usually end with two short paragraphs termed 'general issues' and 'hints for analysis' that nicely and comprehensively summarize the important issues of the procedures treated. This, in conjunction with the clear structure of the content, makes it easy to find what one is searching for. In addition, several chapters give brief but presumably helpful hints for corresponding use of statistical software.

Finally, the book introduces and explains issues and concepts using various biological examples. These examples are almost all published and come mainly from the field of (marine) ecology, but since they are carefully chosen they do not require a deeper understanding of the matter and presumably are generally understandable for all biologists. These examples contribute to the clarity of the book and greatly improve its usefulness for biologists. A particularly user-friendly detail is that the authors provide many of these exemplary data sets as files for download on their homepage. Anyone who ever typed in such examples from books, to test software, will greatly appreciate this.

Beneath all its advantages, the book also has some (mostly minor) disadvantages. For instance, the authors often abbreviate terms like 'randomized complete block' to RCB etc. Although they repeatedly introduce these abbreviations, which are often also rather intelligible from the context, I still missed an overview about abbreviations, preferably at either end of the book. Such an overview would be particularly helpful because in most cases readers will probably read only single chapters or even only parts of them. Similarly, also an overview of the mathematical symbols (as in, e.g. Siegel & Castellan 1988) would greatly increase the usability of the book.

A sometimes disturbing detail is that the book includes some typographical errors. Most of these (e.g. 'out' instead of 'our') do not hinder fluid reading, but some are below what one expects from a book like this. For instance, in a paragraph about 'Replication' (p. 158, chapter 7, 'Design and power analysis') we find an example explaining confounding variables and the need for replication at an appropriate level. It includes the sentence 'note that replication does [not] guarantee protection from confounding because it is still possible that, by chance, all our treatment blocks are different from our control plots in some way besides access to fish' (the variable of interest). The word 'not' (indicated in brackets) is actually missing and I assume that this sentence might be confusing for many readers.

A further disadvantage of the book might be that it, from time-to-time, goes into the details and advanced issues of a procedure to quickly. For instance, at the beginning of the introductory chapter to ANOVA (chapter 8) even the more experienced reader, who is not afraid of the matter, will perhaps lose the thread, since on the first three pages of this chapter he or she is confronted with 'ANOVA', maximum likelihood ('ML') and restricted maximum likelihood ('REML') estimates of variance components. Here, I really wanted a somewhat more basic and 'smooth' introduction and a less extensive use of abbreviations introduced in earlier chapters. However, those who continue reading will still get a lot of useful information. Another point with the first pages of the introductory chapter to (one-way) ANOVA is that the used example could have chosen better. Actually it represents a two-factorial design, and from my understanding it should be analysed as such.

Although Quinn and Keough put much focus on assumptions, I missed some very basic and essential information, in particular in chapters about multivariate statistics. For instance, discriminant function analysis has important requirements with regard to the number of variables relative to the number of cases in the smallest group of objects, or the presumed stability of solutions of a PCA depends on the number of variables relative to the number of cases included in the analysis. Although, to my knowledge, the recommendations given in other texts usually represent empirically derived rules of thumb rather than strict requirements, mentioning these rules would clearly improve the usability of the book.

Finally, I missed a chapter about non-parametric tests. Despite their robustness and ease of use this family of tests also provides a variety of pitfalls and issues that need careful consideration. A brief chapter about the correct treatment of ties, the meaning and importance of the 'correction for continuity', the crucial distinction between exact and approximate p-values, and the fact that these tests have assumptions would have rounded up the book considerably.

Despite these, in fact minor, disadvantages the book is highly recommended. It provides a broad and in-depth overview over most of the commonly used statistical methods. In addition to the conventional methods, it treats multivariate techniques, and describes modern concepts like general and generalized linear models. It particularly focuses on aspects that too often receive not enough attention, like limitations and assumptions, consequences of and alternatives to their violation, as well as interpretation of results under different circumstances. Nevertheless, the potential reader should be warned: this book is, in some parts, far from being at an introductory level (although some chapters are highly recommendable for beginners) and surely cannot replace common text books like e.g. Siegel & Castellan (1988), Sokal & Rohlf (1995), or Zar (1999). Those, however, who have some experience with

the procedures treated but also feel that they could or should know more about them and understand them better, will find the book very helpful. To summarize, the book already became a major source of information for me and I believe that it has the potential to become one of the key statistical references in animal behaviour research.

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The effect of predation risk on foraging and other behaviors has been a hot topic in behavioral ecology in the past 10–15 years, if the 1000+ citations of Lima & Dill (1990) are any indication. However, most studies have been performed in the laboratory, using simple organisms, and there has been a crying need for field studies on a variety of larger species, especially mammals. This book, containing 15 data papers on primates and a well-written introduction by the editor, is an attempt to fill that void. The book is largely successful, although not without some weaknesses.

Simply reporting that predation risk influences foraging behavior is not especially novel or interesting in and of itself. It is important to go beyond this, to examine how food intake and mortality risk are traded off against one another, what this indicates about the decision rules used by the animals, and how it is likely to affect their fitness. Only in this way can one hope to use the knowledge gained to predict the responses of the animals to alterations of their environment. My major criticism of the present collection is that too many papers stop at the first stage. Some are little more than anecdotal reports, with small sample sizes that would make it difficult for them to get published in the primary literature.

One of the problems with studying predator-sensitive foraging in primates is that actual predation attempts are rarely seen in the field. But this problem is certainly not unique to primates, and does not mean that the threat of predation is not real and ever-present in their lives. The best way to estimate the perceived risk level is by testing predictions about how the animals' foraging behavior ought to change with changes in individual (body size, gender), social (group size and composition), and environmental (cover, light level, height above the ground) factors. Most papers in this collection take this approach, and do find support for their predictions. But, this is not always true, especially with regard to cover, which can be a two-edged sword, not only preventing detection by predators, but also obstructing the sight of their approach. More detailed information about predator–prey behavioral interactions, as hard-won as they will be, will be necessary if we are to replace simple predictions with more complex and realistic ones.

Two papers in this collection stand out and will be of particular interest to other readers of 'Ethology' as well. Nancy Caine summarizes previous work and presents new data on a polymorphism in color vision in New World callitrichids (including marmosets and squirrel monkeys). Most callitrichids (like other primates) are trichromats, but within any population, some individuals are dichromats (if they were people we would call them 'color-blind'). Caine suggests that such individuals may be better at spotting camouflaged objects under low light conditions (dawn and dusk) and may be the predator-detecting specialists in the group. Further observational and experimental studies are needed to test this fascinating hypothesis (a recent paper on the genetics of this polymorphism has just appeared in 'TREE'; Surridge et al. 2003).

The other paper that stood out, primarily for the depth and sophistication of its analysis, was on vigilance in chacma baboons by Russell Hill and Guy Cowlishaw. Vigilance levels vary between populations but most of this can be explained by variation in distance to refuge and by the spatial

distribution of food (and thus the proximity of neighboring foragers). Their analysis provides strong evidence that baboons 'manage' their risk level, by adjusting vigilance in an adaptive fashion to local conditions. When animals manage their risk behaviorally, our expectations about how foraging behavior should vary with local conditions may not always be met, i.e. from the animal's perspective the difference in risk may not be as great as we suppose, or as it would have been without such behavioral adjustments. This is a valuable lesson to be borne in mind.

It is noteworthy that Hill and Cowlishaw were among the first authors to consider the role that predation risk might play in the lives of primates. This collection is proof that the concept of predation risk sensitivity, so well supported in other animals, has much of value to say about primate behavior as well, but that there is still much more to be learned.

References

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