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## REPLY TO QUINN AND KEOUGH

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Our goal in Beal and Khamis (1990) was to bring to the attention of the ornithological research community a common, serious statistical problem, namely, treatment of a correlated data set as if it consisted of independent observations. We chose a real data set, rather than a contrived one, that presented additional challenges (such as small sample size).

Quinn and Keough have brought up several points concerning our paper. We respond to comments 1 and 3 and comment on their Table 1.

*Comment 1.* Quinn and Keough state that we repeat the vague claims of the robustness of analysis of variance (ANOVA) procedures that are found in many textbooks. Robustness of ANOVA procedures is a controversial issue among statisticians. Some advocate the use of ANOVA when moderate deviations from the assumptions occur (e.g., Montgomery 1984, p. 87, 91). Zar (1984, p. 170) carefully provides primary references for the robustness of ANOVA, concluding that "... analysis of variance may typically be depended upon unless the data deviate severely from the underlying assumptions." The statement that we used in our paper is somewhat milder than these, more in agreement with Quinn and Keough's own statements in Comment 1. We agree with Quinn and Keough that exploratory data analysis is always advisable. But when the data set is very small, as in this case, normality checks will yield little useful information (Montgomery 1984, p. 86), and tests for homogeneity of variances are unreliable (Zar 1984, p. 183).

*Comment 3.* Quinn and Keough correct a misstatement made concerning the assumptions needed for validity of the repeated measures procedure. We had intended to state that the standard ANOVA assumptions are necessary but not sufficient conditions for the repeated measures procedure. The additional sphericity assumptions mentioned by Quinn and Keough, one form of which is referred to as the Huynh-Feldt conditions (Huynh and Feldt 1970), should have been stated in our paper for informational purposes. However, from a practical point of view, we felt that a discussion of these conditions would contribute little to the point of the paper because they are difficult to test for, especially in a small data set of the type we analyzed, and because of their theoretical complexity. Also, Huynh and Feldt (1980) indicate that some departure from sphericity may not substantially change the nature of the traditional F tests in repeated measures designs (see Read et al. 1988, p. 605–606).

Quinn and Keough suggest two possible alternative forms of analysis. One of these is use of multivariate analysis of variance (MANOVA). We avoided a discussion of this technique because it is our feeling that univariate techniques should be used if possible in order to avoid the additional complexities associated with multivariate procedures. The Greenhouse-Geisser (GG) correction that is used to adjust for violations of the sphericity assumption recommended as the second alternative has been shown in simulation studies to be ultraconservative (Ott 1988, p. 800).

*Concerning Table 1.* There are a number of reasons why Quinn and Keough's numbers in Table 1 differ somewhat from ours:

1. The rates recorded in Tables 1 and 2 of our paper use one decimal place accuracy, as recommended by a reviewer; however, our analyses were based on three decimal place accuracy. Assuming that Quinn and Keough used the rates as recorded in our paper, their ANOVA table results are somewhat less accurate than ours.

2. Our computations were carried out on an IBM 3083 computer using SAS Version 5; Type III sums of squares were used in computing the *F*-ratios.

3. In Table 4, the test for foraging method was conducted *after the nonsignificant interaction term* (foraging × species) *was dropped from the model,* a very common practice when working with ANOVA models; apparently Quinn and Keough did not drop the interaction term from their model when testing for foraging method. Had they dropped this interaction term, the "reversal" of the significant result that they mention in their comments concerning the GG adjustment might not take place. Alternatively, this reversal may be in part due to the ultra-conservativeness of the adjustment—note that the GG *P*-value is somewhat higher than the other two techniques for which the interaction term was not dropped (SYSTAT/SAS and Pillai).

In conclusion, we note that the *P*-values from our ANOVA tables are in general agreement with those given by the other methods presented in Table 1 of Quinn and Keough, with the above comments in mind. In particular, the same general conclusions would be made regardless of which technique is used. Of course, given the sample size and possible violations of assumptions, the *P*-values must be treated as approximations and, as stated in our paper, care must be used in interpreting the ANOVA table.

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