Carfentanil, Bison, and Statistics: The Last Word?

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Source: Journal of Wildlife Diseases, 31(1) : 104-105

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-31.1.104

Journal of Wildlife Diseases, 31(1), 1995, pp. 104–105

LETTER TO THE EDITOR . . .

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Berger and Kock (1988) compared overwinter survival of bison (*Bison bison*) immobilized with carfentanil to survival of untreated bison. They found no significant difference in survival, although sample sizes were small and therefore the power of their test to detect a real difference was low (Halverson and Teare, 1989). Halverson and Teare (1989) also suggested that Fisher's Exact Test was more appropriate for analyzing the data than the Chi-square test used by Berger and Kock (1988).

Berger and Kock (1989) conceded Halverson and Teare's (1989) point that small sample sizes in their 1988 study (21 immobilized animals and 30 control animals) implied a high probability of Type II error: accepting the null hypothesis of no difference in survival between treated and control groups when there really was a difference. Berger and Kock (1989) also presented additional data consistent with the null hypothesis, for bison in Wind Cave National Park, South Dakota (USA). For their original sample from Badlands National Park, three (14%) of 21 immobilized bison disappeared over winter whereas two (7%) of 30 untreated bison disappeared. For the Wind Cave sample, one (4%) of 25 immobilized bison died, whereas none of an estimated 100 untreated bison died. If the Badlands and Wind Cave data are pooled, there is evidence of a significant effect of carfentanil on survival, but Berger and Kock (1989) argued that it would be inappropriate to pool the data because of differences between study sites and methods.

These data are worth reconsidering because neither set of authors used the most appropriate analytical methods, and because a legitimate way to combine the results of studies such as those at Badlands and Wind Cave without pooling the data was presented by Rice (1990) subsequent to the exchange between Berger and Kock and Halverson and Teare. This new analysis leads to a different conclusion than that reached by Berger and Kock (1988, 1989), and suggests caution in use of carfentanil to immobilize bison.

Both the Chi-square test used by Berger and Kock in their 1988 paper and the G-test used in their 1989 paper are problematic because of small sample sizes and because these tests are necessarily 2-tailed. A rule-of-thumb for these analyses of 2×2 contingency tables is that no expected values should be less than 5 (Siegel and Castellan, 1988). For the Badlands data, two of four values are less than 5.0; for the Wind Cave data, two of four are less than 1.0. Because our primary concern is that immobilization with carfentanil reduces overwinter survival, a 1-tailed test of the null hypothesis that it does not reduce survival is more appropriate than a 2-tailed test of the hypothesis that there is no difference between carfentanil-treated and control bison. The latter null hypothesis would be discredited if carfentanil caused increased survival *or* decreased survival; it seems inappropriate to combine these two very different outcomes into one alternative hypothesis for purposes of statistical testing. The Fisher Exact Test used by Halverson and Teare (1989) also is inappropriate because it requires that both sets of marginal totals be fixed. For these data, the numbers of immobilized and control animals can be considered fixed but the numbers of survivors and non-survivors clearly are not fixed (Berger and Kock, 1989). Rice (1988) described a new method for analyzing 2×2 contingency tables which is appropriate for small sample sizes and more powerful than Fisher's Exact Test. Using Rice's (1988) conditional binomial exact test (CBET), the 1-tailed probability that survival is not reduced by immobilization with carfentanil is 0.20 for the Badlands data and 0.09 for the Wind Cave data.

Neither of the individual CBET probabilities is significant at $\alpha = 0.05$, but this isn't convincing evidence against the hypothesis that carfentanil affects survival because sample sizes for both sites were small. Rice (1990) showed how to calculate a consensus probability from results of two or more experiments that test the same null hypothesis. This doesn't involve pooling the data, which would be questionable for the reasons given by Berger and Kock (1989), but rather testing whether the average of the probabilities that the null hypothesis is true in the separate experiments is significantly less than 0.5. For these data, the consensus combined probability that this average is less than 0.5 is 0.06; that is, there is only a 6% chance that survival is not reduced by immobilization with carfentanil. A conservative conclusion from the results of Berger and Kock (1988, 1989) is that immobilization with carfentanil does cause reduced survival of bison, although more data certainly need to be collected to solidify this conclusion.

Several authors (Toft and Shea, 1983; Peterman, 1990; Simberloff, 1990; Shrader-Frechette and McCoy, 1992) have discussed the relative costs of Type I and Type II errors in basic and applied research. These authors, and statisticians in general, agree that rigid adherence to a policy of rejecting the null hypothesis if $P<0.05$ and accepting the null hypothesis otherwise is misguided. Because the probability of accepting a false null hypothesis (making a Type II error) is greater when lower α-levels are used for statistical decision making, the appropriate α is a function of the relative costs of the two types of errors. In this case, the costs of a Type II error arise from using a drug for immobilization that is assumed to have no effect on survival but does in fact decrease survival. For work on endangered species, these costs may be unacceptable. The costs of a Type I error arise from not using a drug for immobilization because it is assumed to decrease survival, whereas in fact it has no effect on survival. If alternative drugs are not available this may delay progress in understanding the biology of the species, by precluding immobilization for attachment of radio-transmitters, collection of blood samples, etc. The decision about which costs to accept will be influenced not only by statistical and biological considerations, but also by economic and ethical concerns. Although this letter may represent "the last word" on the statistical analysis of these data, the question of whether carfentanil should be used to immobilize bison remains unresolved.

I thank J. Berger, R. Duncan, and D. Smith for comments on this note.

LITERATURE CITED

BERGER, J., AND M. D. KOCK. 1988. Overwinter survival of carfentanil-immobilized male bison. Journal of Wildlife Diseases 24: 555–556.

———, AND ———. 1989. Type I and Type II errors in the real world. Journal of Wildlife Diseases 25: 451–454.

HALVERSON, T. G., AND J. A. TEARE. 1989. Carfentanil and overwinter survival in bison: The alternative hypothesis. Journal of Wildlife Diseases 25: 448–450.

PETERMAN, R. M. 1990. Statistical power analysis can improve fisheries research and management. Canadian Journal of Fisheries and Aquatic Sciences 47: 2–15.

RICE, W. R. 1988. A new probability model for determining exact P-values for 2×2 contingency tables when comparing binomial proportions. Biometrics 44: 1–22.

———. 1990. A consensus combined P-value test and the family-wide significance of component tests. Biometrics 46: 303–308.

SHRADER-FRECHETTE, K. S., AND E. D. MCCOY. 1992. Statistics, costs and rationality in ecological inference. Trends in Ecology and Evolution 7: 96–99.

SIEGEL, S., AND N. J. CASTELLAN, JR. 1988. Nonparametric statistics for the behavioral sciences, 2nd ed. McGraw-Hill Book Company, New York, New York, 399 pp.

SIMBERLOFF, D. 1990. Hypotheses, errors, and statistical assumptions. Herpetologica 46: 351–357.

TOFT, C. A., AND P. J. SHEA. 1983. Detecting community-wide patterns: estimating power strengthens statistical inference. The American Naturalist 122: 618–625.

Received for publication 14 July 1994.

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