Response to G. R. Bortolotti and T. W. Arnold

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Bortolotti (1989) and Arnold (1989) both present interesting commentaries on our paper on the consequences of sex-based siblicide on Golden Eagle (*Aquila chrysaetos*) sex ratios (Edwards et al. 1988). Bortolotti (1) posits that our small sample sizes (4–48 fledglings/yr) preclude a statistically effective analysis of population-level deviations in the sex ratio (Edwards et al. 1988). He calculates further that a minimum sample size of 193 birds is required to test for a deviation in sex ratio. Nonstatistical comments include (2) criticism of a test of sex ratio using pooled data, (3) a suggestion that the appropriate test of sex-based siblicide is "whether there was a less than expected number of mixed- versus single-sex broods in years of low food abundance" and (4) a subjective interpretation of our documented relationship between jackrabbit (*Lepus californicus*) abundance and fledgling sex ratio. Last, both Bortolotti and Arnold (5) suggest that the skewed sex ratio we report could be a statistical artifact that resulted from incorrect classification of fledgling sex, and (6) propose alternative analytical methods and interpretations of our data.

Sample-size considerations.—There are, to the best of our knowledge, no formulas to determine sample sizes for a G-test of goodness of fit (review of vols. 4–13, Current Index to Statistics, American Statistical Association, Alexandria, Virginia). In the absence of any reference by Bortolotti, we conclude he used one of many available formulas to determine the minimum sample size necessary to test two independently obtained proportions. Thus, Bortolotti's minimum sample size might be applicable if our stated objective was to test sex ratios at two separate locations. Our explicitly stated goal was to test whether sex ratio deviated from equality, not to compare two separate proportions.

In addition, "There does not seem to be any comprehensive study regarding how small a sample may still be suitable for the G-test of goodness of fit. The usual rule of thumb is that the smallest [expected value] should be five or more" (Sokal and Rohlf 1981: 709). Larntz (1978) suggested that an n 4–5 times the number of cells was adequate, while other "rules of thumb" for expected values range as low as 1.0 (references in Fienberg 1980: appendix IV). Further, to strengthen our analyses, we also applied Williams' (1976) small sample size correction factor to all our tests, a correction that "reduces the value of G and results in a more conservative test" (Sokal and Rohlf 1981: 710). With the exception of one year, appropriately noted (Edwards et al. 1988: table 1), we met the minimum "rules of thumb" detailed above. Although we recognize our sample sizes were small in several years and agree in principle that larger sample sizes are usually better, we reject Bortolotti's specific assertion that our sample sizes needed to be 4–28 times larger to achieve statistical validity.

Testing pooled data.—We recognized that pooling data across all years made it less likely to reject the null when we first developed the manuscript. We blame simple curiosity about overall fledgling sex ratios for including the test.

An alternative hypothesis.—As stated, our objective was to test whether fledgling sex ratios deviated from equality, not whether there existed a nonrandom distribution of mixed- versus single-sex broods. We suggest these represent two different hypotheses. Further, it is difficult to determine how a test of brood composition addresses fledgling sex ratios. To examine the potential impact of sex-based siblicide on fledgling sex ratio still requires an analysis of the frequency of each sex. We agree that Bortolotti presents an interesting hypothesis, but feel it is not germane to the stated goal of our paper.

Jackrabbit abundance and fledgling sex ratios.—One advantage of the statistical method we used to test for a relationship between jackrabbit abundance and fledgling sex ratios (Bulmer 1974: appendix I) is that it eliminates the kind of subjective interpretation made by Bortolotti. Rather than stating that a "time-lag . . . may be evident," one can statistically test for the presence of a time lag. We, too, agree that the visual fit of the two curves is weak and would have preferred to document a much closer fit. Presence of the ≥ 1-yr time lag to which Bortolotti refers would have been indicated by a significant difference between the jackrabbit and fledgling sex ratio curves, a relationship we failed to find. We recognize in retrospect that additional explanation of our use of Bulmer's test would have strengthened our argument, but further explanation would not have altered our results.

Incorrect sex classification.—We agree that the consistent male bias in sex ratio is odd, but are puzzled why Bortolotti and Arnold feel the skewed sex ratio we reported could be a result of the methodology by which we assigned fledgling sex (Edwards and Kochert 1986). Although that manuscript is not the focus of either commentary, we wish to note that all assumptions necessary in discriminant function anal-

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ysis were met (e.g. equality of variance-covariance matrices) and that individual bird posterior classification probabilities were >90%. We feel the developed function correctly sexed fledgling eagles within the limits of the misclassification probabilities reported by Edwards and Kochert.

Arnold's specific criticism that, because our sexing criteria "relied on body mass" alone, there existed a greater possibility of erroneous sex classification is incorrect. We stated explicitly that both body mass *and* footpad length were used to sex fledglings (Edwards et al. 1988). Moreover, Edwards and Kochert modeled the potential error in sex classification because of a full crop whose contents were not subtracted from or added to body weight (over- and underestimation of body weight, respectively). They found that although posterior classification probabilities changed for both males and females, *in no instance was sex classification changed.*

Arnold's additional comment that "discriminant functions are less accurate when applied to new data sets" is a truism and somewhat trivial. Any model is less accurate when applied to a new data set. In the case of Golden Eagles, application of a discriminant function developed from adults to "prefledglings" poses no problem since fledglings past 80% of the mean fledgling age (ca. 52 days of age) have attained mass and footpad measurements characteristic of adults (footpad: Kochert 1972; mass: Collopy 1986). Hence the reason our earliest measurement of eaglet weight and footpad length was at 52 days (Edwards et al. 1988). We have complete confidence in the statistical validity of the discriminant function used to sex fledglings and reject suggestions to the contrary.

Alternative analyses.—We find interesting the observation that Bortolotti provided further support for our work using two additional tests (Mann-Whitney *U*, Kendall rank correlation), while Arnold refuted our hypothesis using a third test (Spearman rank correlation)! Our results, naturally, supported our hypothesis (G-test, Bulmer's test). Rather than argue about the validity of one test relative to another, we invite interested readers to draw their own conclusions and would be happy to make available for reanalysis any necessary raw data.

Arnold also claims that our results were inconsistent with the hypothesis that sex-based siblicide should result in a female-biased sex ratio during years of reduced prey availability. Careful reading of our paper indicates a similar recognition on our part, and we fault Arnold for an apparently superficial evaluation of our manuscript. We quote: "Rather than the predicted shift from an even to a female-biased sex ratio, [we documented a shift from] a male-biased sex ratio towards an even ratio. Thus, shifts in sex ratio were in the appropriate direction with respect to food availability, but were not of the magnitude predicted." (Edwards et al. 1988: 795).

Although our conclusions were confounded by the presence of a consistent male bias in fledgling sex ratio, we reiterate our basic finding: the number of male fledglings relative to females decreased during years of reduced prey abundance, indicating that sex-based siblicide in Golden Eagles may operate as Edwards and Collopy (1983) first postulated. We believe that most of Bortolotti's and Arnold's criticisms are invalid and do not, as Bortolotti asserts, "cast doubt" on whether we effectively examined a potential consequence of sex-based siblicide.

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