————. 1986a. Comparison of the band color preferences of two species of estrilid finches. Anim. Behav. 34: 1732–1741.

————. 1986b. Sexual selection for aesthetic traits in species with biparental care. Am. Nat. 127: 415–445.

————. 1986c. Sex-ratio manipulation in color banded populations of Zebra Finches. Evolution 40: 1191–1206.

————, G. KRANTZBERG, & P. RADMAN. 1982. Influence of color banding on the conspecific pref-

erences of Zebra Finches. Anim. Behav. 30: 444–455.

HAGAN, J. M., & J. M. REED. Red color bands reduce fledgling success in Red-cockaded Woodpeckers. Auk 105: 498–503.

HILL, G. E., & D. E. CARR. 1989. Statistical inference from color banding data. Auk 106: 517–518.

SAS INSTITUTE INC. 1985. SAS user's guide: statistics, 1985 ed. Cary, North Carolina SAS Institute Inc.

Sex Ratios of Fledgling Golden Eagles

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Edwards et al. (1988) examined sex ratios of fledgling Golden Eagles (*Aquila chrysaetos*) over a 15-yr period in Idaho. Their analysis addressed potential deviations from a 1:1 sex ratio each year and for all years combined, and the potential relationship between prey abundance and eagle sex ratios. The rationale was that in times of food shortage brood reduction commonly occurs; large siblings restrict access to food of small siblings. The relative size of nestling eagles, and hence the probability of siblicide, depends in part on each bird's sex (females are larger than males [Bortolotti 1984, Edwards and Kochert 1986]) and order in the hatching sequence (Bortolotti 1986a). Edwards and Collopy's (1983) measurements of nestlings, and Bortolotti's (1986b) more theoretical argument, both suggest that brood reduction in two-chick broods of Golden Eagles is most likely to occur when a female hatches before a male (F-M). There is less of a size difference between siblings for other combinations of sex and hatching sequence (M-F, F-F, M-M) (Bortolotti 1986).

Edwards et al. (1988) stated correctly that the "tendency for the occurrence of siblicide in F-M broods should be manifest in population-level fledgling sex ratios." However, some statistical considerations cast doubt as to whether Edwards et al.'s analyses can test effectively sex ratios at the population level.

In the original analysis, sample size was a major problem. The number of fledglings ranged from 4 to 48 per year, and the number of broods varied between 3 and 28 per year. Analysis of the sex ratio of each year's cohort was tested against a 1:1 ratio using nestlings from broods of all sizes (Edwards et al. 1988: table 1). The hypothesis that brood reduction results

in an excess of females might have been better tested by examining broods with only a single fledgling. The sex ratio of one-chick broods should be biased, but that of two-chick broods should not. Limited sample size may have been a problem for such an analysis; however, inclusion of broods in which no mortality from brood reduction has occurred makes matters worse.

Consider the following possible, although extreme, example. All broods initially contain two offspring, and sex and hatching sequence are independent. All F-M broods experience brood reduction but mortality of nestlings in other broods is independent of sex. If such were the case, the population's true sex ratio would be 0.75 (male/female). In an analysis that lumps one- and two-chick broods, 0.75 is the most strongly female-biased sex ratio possible (excluding stochastic events), and is the easiest to test statistically. The minimum sample size required to find a significant difference between a ratio of 1 and 0.75 would be about 193 birds (i.e. 4–28 times larger than the sample sizes tested by Edwards et al.). If single-chick broods resulting from the hatching of only one egg or from random sources of mortality unrelated to siblicide are included, as was presumably done by Edwards et al., the sex ratio increases and the analysis requires even larger samples. Therefore, a test of the sex-biased siblicide hypothesis using sex ratios of cohorts requires a reanalysis, larger sample sizes, or both.

Edwards et al. also tested the sex ratio of all years combined ($n = 320$ birds). This is a poor test of the hypothesis of sex-biased siblicide because mortality in F-M broods would be expected only in times of poor food resources (9 of the 15 years in their study). The sex ratio of the combined sample would be some unknown degree greater, presumably much greater, than 0.75. It may have been more profitable to examine the distribution of the sexes in two-chick broods

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(i.e. whether there was a less than expected number of mixed-sex versus single-sex broods [see Bortolotti 1986b] in years of low food abundance).

Edwards et al. (1988) present some interesting and provocative results: in particular, recognition of the coincidence in temporal patterns of prey abundance and sex ratios. However, sex ratios and prey numbers do not appear to coincide as closely as one might expect if brood reduction were the causal factor. In the first few years of study, prey abundance declined, yet the proportion of males increased. Similarly, in the last few years, prey numbers were low, yet the percentage of males was very high. A time-lag between prey abundance and proportion of males may even be evident (see their fig. 1).

The data presented by Edwards et al. (1988) allow additional statistical analyses. If a food shortage increased the frequency of brood reduction, then the mean brood size in low-food years should be less than in high-food years. A one-tailed Mann-Whitney U test of this is significant ($U = 10.5$, $P < 0.05$). According to the sex-biased siblicide hypothesis, the percentage of males that fledge in the population should be inversely related to the average brood size. A Kendall rank correlation was nearly significant ($\tau = 0.289$, $P = 0.069$, one-tailed), offering weak support for the general conclusions in the original paper.

One advantage of the previous analysis is that it does not require a prediction of what the sex ratio should be in the absence of siblicide. The assumption of a 1:1 sex ratio is problematic for Edwards et al. (1988) because their population has a disproportionate number of males. They propose that siblicide depresses the male bias, but they do not offer an explanation for why the bias exists in the first place. The

strongly skewed sex ratios could be artifacts of small samples, or the result of a bias in assigning sex to fledglings on the basis of size (Edwards and Kochert 1986). It seems plausible that something out of the ordinary is happening with eagle sex ratios; however, testing only the sex-biased siblicide hypothesis seems too limited for this phenomenon.

LITERATURE CITED

BORTOLOTTI, G. R. 1984. Age and sex size variation in Golden Eagles. J. Field Ornithol. 55: 54–66.
———. 1986a. Evolution of growth rates in eagles: sibling competition vs. energy considerations. Ecology 67: 182–194.
———. 1986b. Influence of sibling competition on nestling sex ratios of sexually dimorphic birds. Am. Nat. 127: 495–507.
EDWARDS, T. C., JR., & M. W. COLLOPY. 1983. Obligate and facultative brood reduction in eagles: an examination of factors that influence fratricide. Auk 100: 630–635.
———, ———, K. STEENHOF, & M. N. KOCHERT. 1988. Sex ratios of fledgling Golden Eagles. Auk 105: 793–796.
———, & M. N. KOCHERT. 1986. Use of body weight and length of footpad as predictors of sex in Golden Eagles. J. Field Ornithol. 57: 317–319.

Sex Ratios of Fledgling Golden Eagles and Jackrabbit Densities

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Edwards et al. (1988) documented significant ($P < 0.05$) male-biased deviations from a 1:1 sex ratio among fledgling Golden Eagles (*Aquilo chrysaetos*) during three years (1979, 1981, 1983) and throughout their study (1970–1984). They suggested that biased sex ratios resulted from higher frequencies of facultative siblicide in mixed-sex broods. Female offspring are larger than similar-age males; siblicide should thus occur most frequently among mixed-sex broods in which the female hatches first, because nestling size disparities are largest in such broods (Edwards and Collopy 1983, see also Bortolotti 1986). Edwards et al. predicted that

if facultative siblicide is directed disproportionately towards male offspring and if it occurs most frequently when prey are scarce (but see Mock 1985, Simmons 1988), then the proportion of males in the fledgling population should increase with prey abundance.

Edwards et al. claimed that they found support for this prediction, but this support came by a very circuitous route. They fitted sine curves with 10-yr periodicities to 14 and 15 yr of data on black-tailed jackrabbit (*Lepus californicus*) abundances and fledgling sex ratios (proportion of males), respectively, and observed that both curves were explanatory ($P < 0.05$), and furthermore, that the two curves were not significantly different ($P = 0.57$). They therefore concluded that "fledgling sex ratio was highly correlated with jack rabbit density" (p. 795).

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