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SHORT COMMUNICATIONS

Do standardized brood counts accurately measure productivity?—A standardized method for estimating raptor reproductive success and productivity is crucial for making valid comparisons among years and populations (Steenhof 1987). Steenhof and Kochert (1982) recommended that reproductive surveys be conducted when nestlings reach 80% of the average fledging age because nestlings are easily counted (Steenhof 1987), and little mortality occurs after this age and prior to fledging (Millsap 1981, Steenhof 1987). The utility of this recommendation would be enhanced if the number of nestlings reaching 80% of average fledging age was also indicative of a pair's productivity later in the nesting cycle. We tested this relationship in Prairie Falcons (*Falco mexicanus*) by measuring productivity at 80% of fledging age and at the end of parental care (approximately 35 days later or 27 days after fledging; McFadzen and Marzluff, unpubl. data). This latter measure of productivity was selected because attributes of habitat and land-use around nesting areas may affect productivity throughout the nesting period until parental care ceases and fledglings disperse.

In conjunction with a multi-year study of Prairie Falcon productivity (Lehman et al. 1993, Marzluff et al. 1993) in the Snake River Birds of Prey National Conservation Area in southwestern Idaho (area described in U.S.D.I. 1979), we knew the number of nestlings reaching 80% of fledging age and the number subsequently dispersing from the natal territory for 58 broods during the 1992 and 1993 breeding seasons. This sample included all sites we knew failed to produce fledglings (N = 24) and 34 sites where we radio-tagged nestlings (N = 141) and monitored their survival to dispersal (McFadzen and Marzluff, unpubl. data).

The number of nestlings attaining 80% of fledging age was significantly correlated with the number of young dispersing from a territory (Fig. 1; $r = 0.83$, $P < 0.001$, N = 58 broods), but the number of young per brood that survived to disperse differed substantially from the number of nestlings attaining 80% of fledging age. This difference was significant for broods of four (Paired $t = -3.2$, 11 df, $P = 0.008$) and broods of five to six (Paired $t = -3.9$, 16 df, $P = 0.001$) but not for broods of one to three (Paired $t = -1.6$, 4 df, $P = 0.18$). The relative inaccuracy of predicting the number of dispersers from the number of nestlings attaining 80% of fledging age was indicated by the large 95% confidence intervals associated with the mean difference between these two measures. The mean number of nestlings attaining 80% of fledging age was expected to be larger than the number of dispersers by up to 1.47, 3.91 and 4.37 nestlings, respectively for broods of three size classes (1–3, 4, and 5–6 nestlings; upper 95% confidence limits for difference between two means using one-sided confidence intervals; Hahn and Meeker 1991).

Variation in the number of young dispersing from broods of a given size required brood size to differ by at least two nestlings before significant differences in the numbers of dispersers were observed. The number of young dispersing from broods of one, two, or three (pooled $\bar{x} \pm$ SE = 1.2 ± 0.51, N = 5) did not differ significantly from the number dispersing from broods of four ($\bar{x} \pm$ SE = 2.7 ± 0.33, N = 12; Tukey's pairwise comparison, $P = 0.08$). The number dispersing from broods of four was not different from the number dispersing from broods of five or six (pooled $\bar{x} \pm$ SE = 3.5 ± 0.4, N = 17; Tukey's pairwise comparison $P = 0.20$). Broods of five or six produced more dispersers than broods of one, two, or three (Tukey's pairwise comparison, $P = 0.001$).

The significant correlation between the number of nestlings attaining 80% of fledging age and the number dispersing verifies that standardized nestling counts are indicative indices of a pair's productivity. However, we suggest that caution be applied in interpretations of

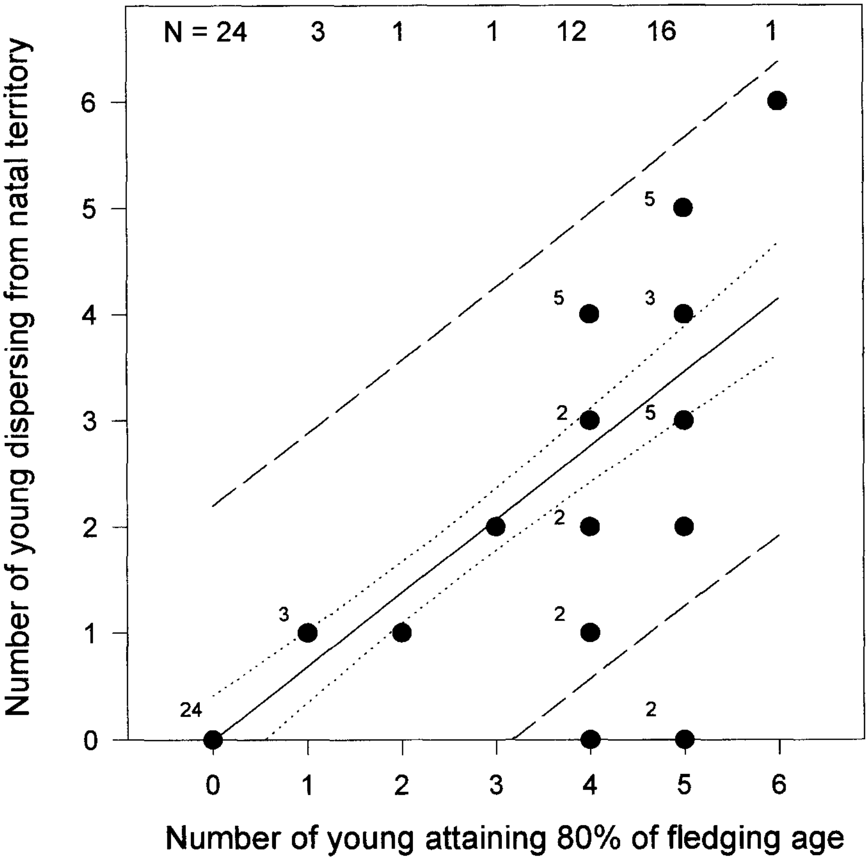

FIG. 1. Relationship between the number of young attaining 80% of fledging age (brood size) and the number surviving to disperse from the natal territory 35 days later. Sample sizes for each brood size are totalled at the top of the figure and listed next to each point with multiple observations. The least-squares regression line (solid line) and associated 95% confidence (dotted lines) and prediction intervals (dashed lines) are plotted.

brood counts as a measure of productivity for two reasons. First, brood counts may not accurately reflect the number of young fledging from the site. From 16% to 50% of young attaining 80% of fledging age died before they fledged (McFadzen and Marzluff, unpubl. data), and many more died before they dispersed (Fig. 1). Second, there was considerable variation in the number of dispersers produced from larger broods so that prediction intervals were large (Fig. 1) and brood counts needed to differ by at least two nestlings for differences to remain significant ($P < 0.05$) until the end of parental care. If a study compared a large number of broods between treatments (e.g., years, study areas, etc.), the resulting statistically powerful test could provide misleading conclusions about differences in productivity by showing that brood counts differing by less than two nestlings were significantly different ($P < 0.05$).

We support the use of standardized measures of productivity but urge researchers to measure productivity as late in the nesting cycle as possible. Measurements at earlier stages, such as Steenhof (1987) proposes, can be used to rank pairs in order of their productivity and to discriminate most successful pairs from failed ones. This may be adequate for studies designed to survey avian use of an area and to contrast the probability of successful reproduction among treatments. However, studies designed to compare brood counts among treatments, understand the demography of a population, or understand the factors that influence the reproductive success of individuals should not rely on measures of productivity made early in the nesting cycle because these are unlikely to correlate precisely with the number of young surviving to later stages.

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