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EFFECTS OF MIST NETTING ON REPRODUCTIVE PERFORMANCE OF WRENTITS AND SONG SPARROWS IN CENTRAL COASTAL CALIFORNIA

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Abstract. Mist netting is widely used to monitor the reproductive success of passerines, yet little is known about its effects on bird ecology. Using a 25-year data set from central California, we evaluated the effects of constant-effort mist netting on the reproductive performance of the Wrentit (*Chamaea fasciata*) and Song Sparrow (*Melospiza melodia*). We compared nest survival, number of young fledged, and an index of nestling condition (mass corrected for body size) at nests where at least one parent was captured while the nest was active to these variables at nests where neither parent was captured. We also compared these characteristics for nests at varying distances from nets run at different frequencies. Wrentit nestlings from nests closer to less frequently run nets were in poorer condition than those from nests close to more frequently run nets and than those far away from any nets. For the Song Sparrow, daily nest survival was higher where at least one parent was captured while the nest was active. For all other comparisons, there was no statistical evidence that mist netting had an effect on reproductive performance of these species. This information should ease concerns about the use of mist nets in monitoring avian demographics.

Key words: Chamaea fasciata; *daily nest survival; effects;* Melospiza melodia; *monitoring; mist net; reproduction; Song Sparrow; Wrentit.*

Efecto del Uso de Redes de Niebla sobre el Desempeño Reproductivo de *Chamaea fasciata* y *Melospiza melodia* en la Costa Central de California

Resumen. La captura con redes de neblina es usada ampliamente para monitorear el éxito reproductivo de aves paseriformes, sin embargo se sabe poco sobre sus efectos sobre la ecología de las aves. Utilizamos una base de datos de 25 años proveniente del centro de California y evaluamos los efectos del esfuerzo constante de captura con redes de niebla sobre el desempeño reproductivo de *Chamaea fascista* y *Melospiza melodia*. Comparamos la supervivencia de nidos, el número de polluelos y un índice de condición de los polluelos en el nido (peso corregido por el tamaño corporal), para nidos en los que por lo menos uno de los padres fue capturado mientras el nido estaba activo y en nidos en que ninguno de los padres fue capturado. También comparamos estos parámetros entre nidos que se localizaban a distancias variables desde los puntos en que se operaban redes con diferente frecuencia. Los polluelos de *C. fascista* de nidos localizados cerca de redes operadas con baja frecuencia se encontraron en peor condición que aquellos polluelos de nidos localizados más cerca de redes operadas frecuentemente y de nidos ubicados lejos de cualquier red. Para *M. melodia*, la supervivencia diaria de nidos fue mayor para aquellos nidos en que por lo menos un padre fue capturado mientras el nido estaba activo. Para todas las otras comparaciones, no hubo evidencia estadística de que las redes tuvieran un efecto sobre el desempeño reproductivo de estas especies. Esta información debería disminuir las preocupaciones sobre el uso de redes durante los monitoreos.

INTRODUCTION

Ethical and scientific concerns require that investigators understand the effects their research has on the animals they study. For birds, there is a large body of literature on investigators' effects, including those at the nest, on behavior and fitness (O'Grady et al. 1996, Sandvik and Barrett 2001, Verboven et al. 2001, Richardson et al. 2009). Other studies have compared the effects of a variety of capture, handling, and marking techniques (Nisbit 1981, Ballard et al. 2001, Phillips et al. 2003, Reed et al. 2005, Dugger et al. 2006). Results from these studies span the spectrum from no effect to effects so substantial that the authors concluded some techniques may prevent reliable research (Salathe 1987).

Data from constant-effort mist netting are widely used to estimate productivity in passerines (Bollinger and Linder 1994, Gardali et al. 2000, Dunn et al. 2004), and large-scale monitoring programs rely on this method to index reproductive success (DeSante et al. 1995, Peach et al. 1996). Despite this wide use, studies of the direct effects of mist-netting on reproductive success are lacking.

Constant-effort mist netting may reduce reproductive success by reducing nest attendance while captured birds

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are in the net and being processed. During this time, nests may face an increased risk of predation and parasitism, and eggs or young may suffer from lack of incubation or brooding. Furthermore, capture and handling may cause a change in parental behavior or health that could reduce reproductive performance (Davenport et al. 2004). Independent of captures, mist netting may also affect reproductive performance through the human activity associated with operating mist nets near nests (Nisbit 1981). This activity may disturb parents enough to reduce reproductive success, or, conversely, it may discourage predators from using the area around the nest (Churchwell and Barton 2006, Reed and Merenlender 2008) and so increase reproductive success.

Evaluating the effects of mist netting on reproductive success requires comparing the success of nests in areas with and without mist nets. At the Palomarin Field Station, PRBO Conservation Science has compiled long-term data with constant-effort mist netting and nest monitoring, operating two mist-net arrays in subsets of the plots where nests are monitored. Here, we use 25 years of data to compare the productivity of nests where at least one parent was captured while the nest was active to that of nests where neither parent was captured. We evaluated the effect of distance of the nest from nets run at different frequencies. We investigated three measures of reproduction: nest survival, nestling condition, and number of offspring that fledged.

METHODS

STUDY SITE AND FOCAL SPECIES

The Palomarin Field Station is located within the Point Reyes National Seashore in central coastal California (Fig. 1). The study area is 36 ha covered largely with dense coastal scrub;

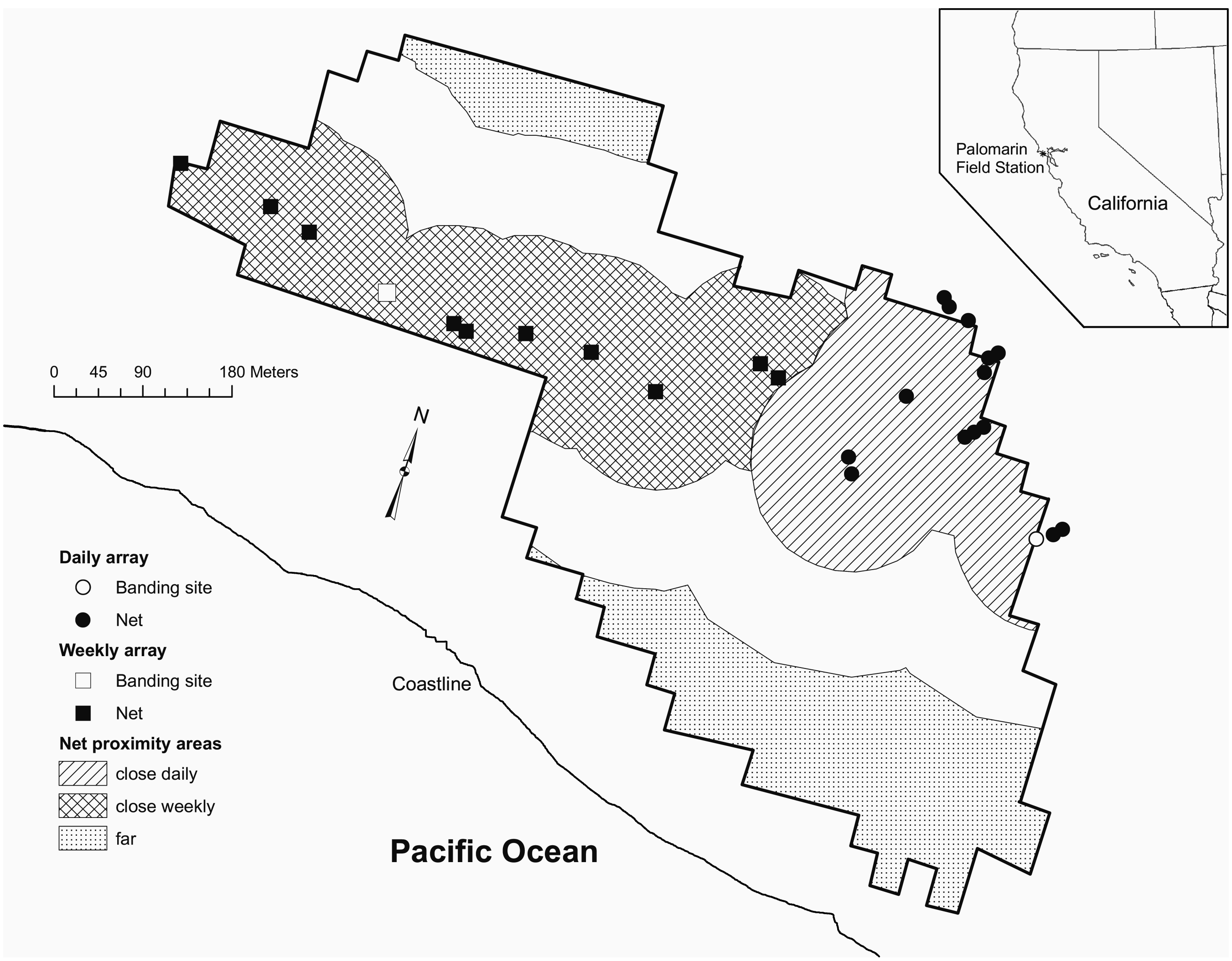

FIGURE 1. Areas contained by each net-proximity category and locations of banding sites and arrays of mist nets run daily and weekly at Palomarin Field Station, Marin County, California.

over the course of the study, however, the coverage of short (4–8 m) Douglas-fir (*Pseudotsuga menziesii*) increased. The habitat and the demography and composition of the avian community were rather uniform across the entire study site; small-scale variations in habitat did not cause systematic differences among plots. For detailed description of the study site see Silkey et al. (1999) and Chase et al. (2005).

We focused on two species commonly caught and thoroughly monitored at the study site: the Wrentit (*Chamaea fasciata*) and Song Sparrow (*Melospiza melodia*). At this site, both are year-round residents, socially monogamous, open-cup nesters, and often attempt two broods per breeding season (Geupel and Ballard 2002, Chase et al. 2005).

DATA COLLECTION

Nest monitoring. Each year during the breeding seasons (March–August) of 1982–2006, nests were found and monitored by three or four biologists using standard methods (Martin and Geupel 1993). They checked nests every 2–4 days and determined the nests' outcome by a combination of timing, parental behavior, and direct observation of the fledglings. The number of young fledged was determined, when possible, by a count of the fledglings or by the number of nestlings present on the last check before fledging. Under the supervision of the same biologist (GRG) each year, maps showing territories and all nest locations were drawn. On approximately day 10 (Wrentit) or day 7 (Song Sparrow) after hatching, nestlings' mass was measured (to 0.1 g) with a portable electronic scale or, occasionally, a Pesola spring scale (to 0.5 g), and nestlings were fitted with unique combinations of one U.S. Department of the Interior (USDI) aluminum band and three plastic colored bands. Starting in 1996, tarsi were measured (±0.1 mm) with calipers. The day of banding varied slightly because of uncertainties in the precise age of nestlings and the logistics of field work. These variations, however, were not consistent within any one treatment class and likely did not cause any bias.

Constant-effort mist netting. Ballard et al. (2004) described operation of the two mist-net arrays at Palomarin in detail. Features of particular relevance to our analysis: The "daily" array (20 nets at 14 sites; 6 sites had 2 nets stacked vertically) was operated 6 days week^{-1} for the entire study period (Fig. 1). Operation of the "weekly" array (10 single nets run once, occasionally twice, every 10 days) began in 1992. The arrays were adjacent with roughly the same habitat, slope, exposure, and elevation. Operation of the "weekly" array followed the Monitoring Avian Productivity and Survivorship protocol (DeSante et al. 2004). Within both arrays the nets' locations remained constant throughout the study. Captured Wrentits and Song Sparrows were marked with a unique combination of a USDI aluminum band and three plastic colored bands.

Total time that birds were held from capture until release ranged from 10 to 80 min, though this time was not recorded for individual birds. To reduce the potential negative effects of long handling times on nesting success, all adults caught during the breeding season were checked at the net for breeding condition, and individuals with a developed brood patch were prioritized for rapid processing. Additionally, all individuals were released near the net in which they were captured. Nets were typically checked every half hour but at times as frequently as every 15 min. Nets were not operated if it was abnormally hot or cold, was windy, or if precipitation or fog caused water to collect on the nets.

STUDY DESIGN

We evaluated the effects of mist netting on reproductive performance with two approaches. The first (parent-capture) examined the direct effects of mist-net capture on nesting birds. Nests from all three net-proximity classes (see below) were pooled then classified either as having at least one parent caught ("caught") while the nest was active or as having neither parent caught ("not caught"). Nests with parents caught either before or after the nest was active were considered "not caught." We considered nests active from the date the first egg was laid until the young fledged or the nest failed. For nests found with eggs or young, we used local knowledge of nest period to estimate the date of the first egg (Geupel and Ballard 2002, Chase et al. 2005).

Our second analysis (net-proximity) investigated the indirect effects of mist netting in the general vicinity of nesting Wrentits and Song Sparrows. To better distinguish between indirect effects associated with activity and direct effects associated with capture, in the net-proximity analysis we used only nests from which neither parent was captured. At Palomarin, many individuals of both species holding territories within 100 m of mist nets are caught during the breeding season, while at distances greater than 200 m the ability of mist nets to capture territorial individuals falls off significantly (Silkey et al. 1999, Ballard et al. 2004, Nur et al. 2004). We split the area of nest searching into sections defined by proximity to mist nets: "close daily" (within 100 m of the "daily" array, see above), "close weekly" (within 100 m of the "weekly" array), and "far" (>200 m from any mist net; Fig. 1). Nests between 100 and 200 m from mist nets were not considered. Nests located within an area of overlap between the close-daily and close-weekly portions of the study site were classified as close daily. Prior to 1992, when we instituted the weekly array, nests in what would become the close-weekly area were either classed as far (if they were >200 m from the daily array) or not considered (if they were between 100 and 200 m of the daily array).

Using territory/nest location maps, we assigned nests to a particular class if the nest itself and at least half of the birds' territory fell within the corresponding zone. The close-daily area was ~6.2 ha, the close-weekly area ~10.1 ha. The far area ranged from 200 to 390 m from nets and comprised ~21.6 ha before 1992 and 7.9 ha after 1992 (when operation of the weekly array was begun).

STATISTICAL ANALYSES

In both the parent-capture and net-proximity comparisons we evaluated three measures of reproductive success. We used only the first nest recorded for each female each year. This limited psuedoreplication of multiple nests from the same female and reduced complications arising from the greater likelihood of capture for birds nesting closer to nets. Nests of the same female were used if from different years. See Discussion for more detail.

Nest survival. We calculated daily nest survival and 95% confidence intervals by following the suggestions of Mayfield (1975) and Johnson (1979). We chose the Mayfield estimator over alternative methods of estimating nest success (e.g., logistic exposure) because (1) we were comparing categories of data that were grouped a priori and (2) our large sample size allowed for precise estimates. Under these conditions, inferences from Mayfield estimates and other nest-success estimates are generally similar (Johnson 2007, Lloyd and Tewksbury 2007). We then compared daily nest survival and 95% confidence intervals by class within each group. We considered differences statistically significant if 95% confidence intervals did not overlap. Chase (2005) reported that at Palomarin the daily survival of Song Sparrow nests at the laying, incubation, and nestling stages did not differ. If there were stage-based differences in daily nest survival, we assume they would be similar in all plots and thus would not influence our results.

Number of fledglings. At Palomarin, clutch sizes range from 1 to 5 for the Wrentit and from 1 to 4 for the Song Sparrow (Geupel and Ballard 2002; PRBO, unpubl. data). We compared the median number of fledglings per successful nest by group with a Kruskal–Wallis test (Zar 1999). We defined a successful nest as one that fledged at least one young, regardless of how many eggs had been laid.

Nestling condition. After $\log_{10}$-transforming both tarsus and body mass, we used reduced major-axis regression to determine the relationship between mass and tarsus length. We used the residuals from this regression as an index of a bird's condition, corrected for the bird's size (Green 2001). We then averaged the condition index of all nestlings within a nest to generate a single measure of nestling condition for each nest and compared these averaged indices with a Kruskal–Wallace test (Zar 1999). Nestlings' tarsi were measured beginning in 1996, thus this analysis uses data from 1996 to 2006.

All analyses and graphics were done with R Version 2.6.1 (R Development Core Team 2007).

RESULTS

DAILY NEST SURVIVAL

The probability of daily nest survival was significantly greater for Song Sparrow nests from which one or more parent had been captured (difference of 0.037, caught $n = 42$, not caught $n = 394$; Fig. 2C). The absolute difference in overall nest-survival probability (with a 26-day nest period) between nests from which at least one parent had been caught and those from which neither parent had been caught was 31%. Daily nest survival did not vary by parent-capture class for the Wrentit (caught $n = 45$, not caught $n = 454$) or by net-proximity class for either species (Wrentit: close daily $n = 94$, close weekly $n = 94$, far $n = 266$; Song Sparrow: close daily $n = 127$, close weekly $n = 52$, far $n = 215$). For all three of these categories daily nest survival was nearly identical, and all 95% confidence intervals overlapped substantially (Fig. 2A, B, D).

NUMBER OF FLEDGLINGS

For both species, we found no difference among the parent-capture classes in number of young fledged per nest (Kruskal–Wallace test, Wrentit: $\chi^2_1 = 0.034$, $P = 0.854$; caught $n = 22$, not caught $n = 152$; Song Sparrow: $\chi^2_1 = 0.002$, $P = 0.969$; caught $n = 13$, not caught $n = 78$; Fig. 3A, C). Nor did we find any difference among the net-proximity classes (Kruskal–Wallace test, Wrentit: $\chi^2_2 = 3.28$, $P = 0.194$; close daily $n = 40$, close weekly $n = 53$, far $n = 59$; Song Sparrow: $\chi^2_2 = 0.586$, $P = 0.746$; close daily $n = 24$, close weekly $n = 21$, far $n = 33$; Fig. 3B, D).

NESTLING CONDITION

We detected no difference in nestling condition among parent-capture classes for either species (Kruskal–Wallace test, Song Sparrow: $\chi^2_1 = 2.070$, $P = 0.150$; caught $n = 38$, not caught $n = 172$; Wrentit: $\chi^2_1 = 0.012$, $P = 0.913$; caught $n = 41$, not caught $n = 322$; Fig. 4A, C). For the Song Sparrow, we detected no difference in nestling condition among net-proximity classes ($\chi^2_2 = 2.513$, $P = 0.285$; close daily $n = 81$, close weekly $n = 63$, far $n = 66$; Fig. 4D). For the Wrentit, however, nestling condition in one net-proximity class did differ (Kruskal–Wallace test, $\chi^2_2 = 11.029$, $P = 0.004$; close daily $n = 111$, close weekly $n = 133$, far $n = 119$). The condition index of nestlings from nests in the close-daily and far groups were similar to each other and greater than that of nestlings from the close-weekly group (Fig. 4B).

To take advantage of the larger sample size, we reran all our analyses with all recorded nesting attempts, and in all three measures of reproductive success found patterns very similar to those reported above. The only difference was that daily nest survival of both Wrentits and Song Sparrows was higher for nests with at least one parent caught.

Because we believe researchers should also consider effects on individual birds when evaluating mist-netting and banding studies (Pierce et al. 2007), we report here the injury and mortality rates at Palomarin for this period of banding. For the Wrentit, these were 0.2% and 0.06%, respectively, for the Song Sparrow, 0.3% and 0.15%, respectively. These percentages include minor injuries such as wing strain as well as major ones such as broken legs.

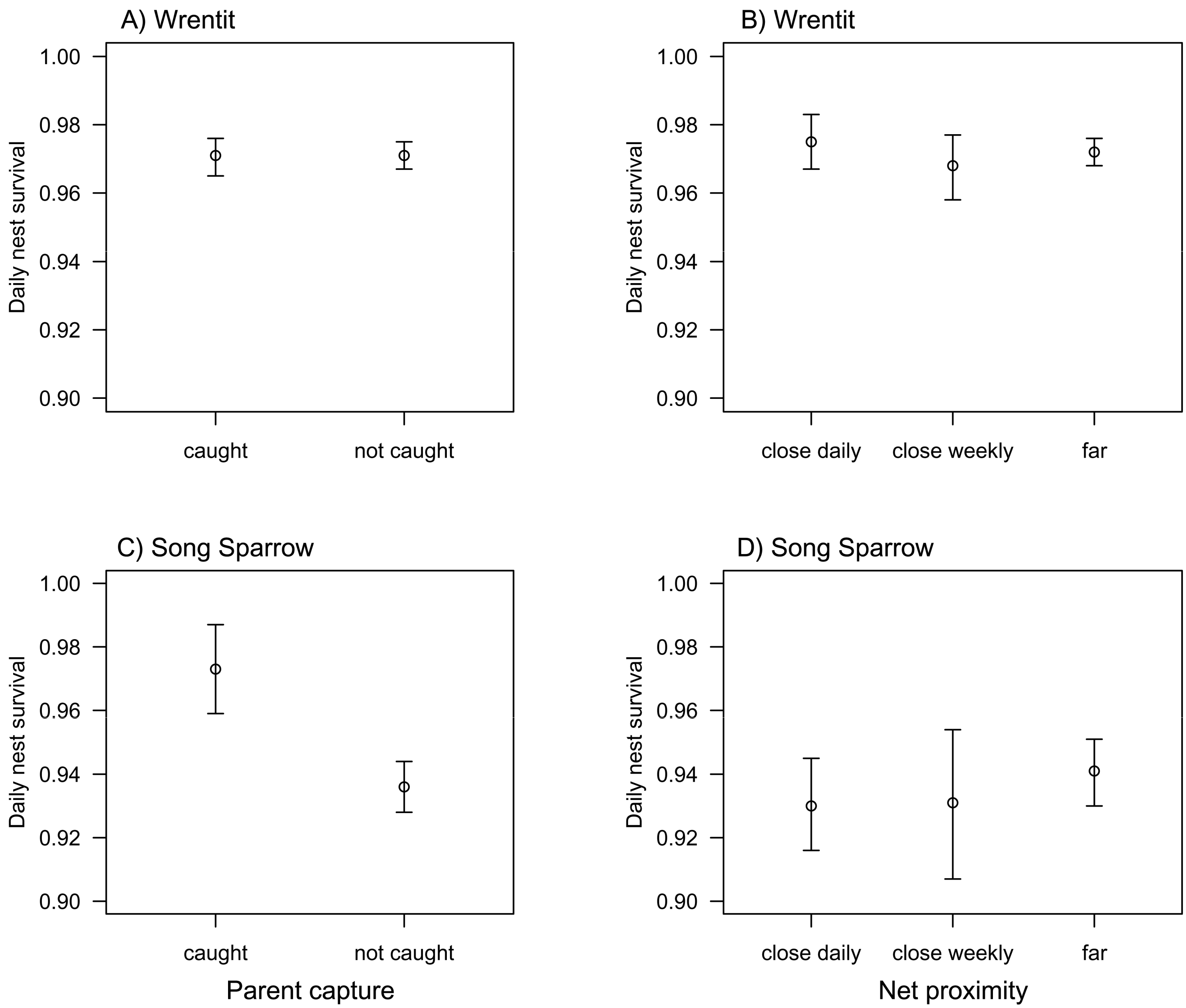

FIGURE 2. Daily survival of Wrentit and Song Sparrow nests in both parent-capture (A, C) and net-proximity (B, D) groups at the Palomarin Field Station, California, from 1982 to 2006; 95% confidence intervals are shown.

DISCUSSION

The differences we found in reproductive performance of Wrentits and Song Sparrows were neither large nor consistent between species or across the parent-capture or net-proximity classes. In part, this may result from specific protocols used at Palomarin to minimize effects on breeding birds (rapid processing of incubating individuals, ceasing net operation in inclement weather, etc.). The only difference found in association with mist-net captures (higher daily nest survival of captured Song Sparrows) was not intuitively consistent with our expectations about the effects of mist netting on reproductive success.

The only negative effect our data indicated was the reduced condition index of Wrentit nestlings from nests located within 100 m of the array of nets run weekly. This result is perplexing because we expected that the greatest effects, either positive or negative, would be associated with nets that were run most frequently. Net avoidance has been shown to increase with increasing frequency of mist-net operation (overview in Remsen and Good 1996), suggesting habituation to mist netting by some species or individuals. Perhaps mist netting at Palomarin disturbs reproduction more when it is conducted less frequently because individuals do not become habituated to mist nets. Investigating the effects of a wider range of frequencies of mist netting may shed light on this subject.

The second difference we observed in reproductive success in relation to mist-netting effort was a higher daily

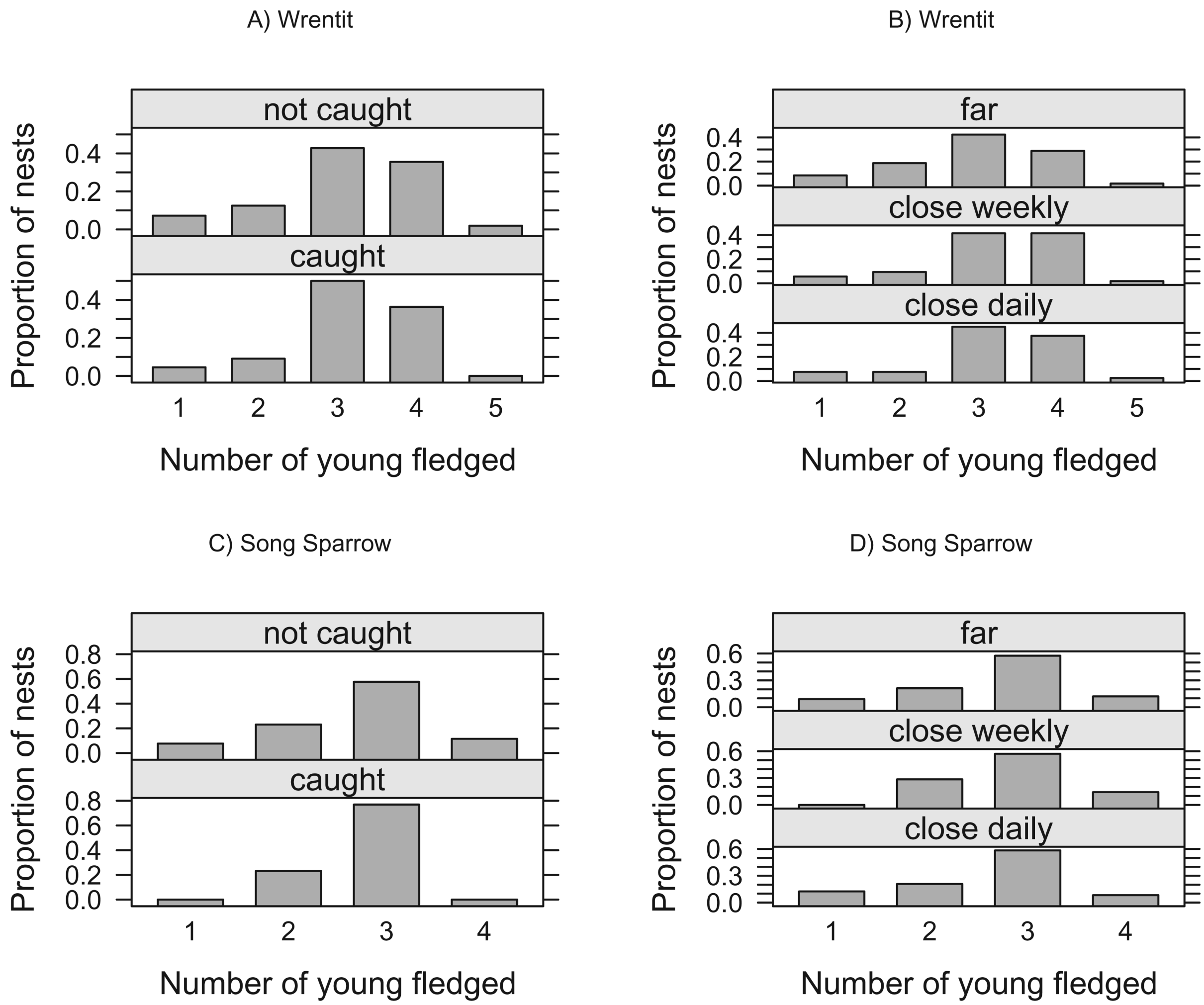

FIGURE 3. Number of young fledged from Wrentit and Song Sparrow nests in the parent-capture (A, C) and net-proximity (B, D) groups at the Palomarin Field Station, California, from 1982 to 2006.

survival of Song Sparrow nests from which at least one parent was caught while the nest was active. We know of no mechanism by which the capture of nesting adults should directly cause such a result, and this relationship is likely correlative rather than causative. For example, in the Great Tit (*Parus major*), Hollander et al. (2008) showed that individuals making more exploratory movements also defended their nests more, and Both et al. (2005) showed that nests with two "high-exploring" parents produced fledglings in better condition than those with only one high-exploring parent. If a similar relationship exists for the Song Sparrow at Palomarin, parents with higher reproductive performance may have been captured in mist nets more frequently.

Some limitations of this study should be considered when our results are interpreted. In all analyses, we treated nests as independent replicates. We recognize that in the absence of randomized assignments of nests to categories, the effects of mist-net capture or operations could be confounded by preexisting differences among the plots (Hurlbert 1984). While recognizing the importance of pseudoreplication (Hurlbert 1984), we believe our analysis was justified because the boundaries of the distance categories did not reflect any habitat differences across the study site and were based solely on the nets' locations. To investigate possible differences among the plots, we compared the dates of clutch completion by plot for both first-recorded attempts and all attempts together; these were remarkably similar for all plots. Furthermore, the breeding performance of other avian species, structure of the avian communities, and habitat structure were all generally uniform across the study site (PRBO, unpubl. data). Therefore, we infer that all nests experienced similar conditions other than distance to nets. Because of site fidelity in these resident species, in successive years nests frequently represented the reproductive effort of the same pair; successive nests of individuals were usually located in the same net-proximity class. Nonetheless, because our data spanned

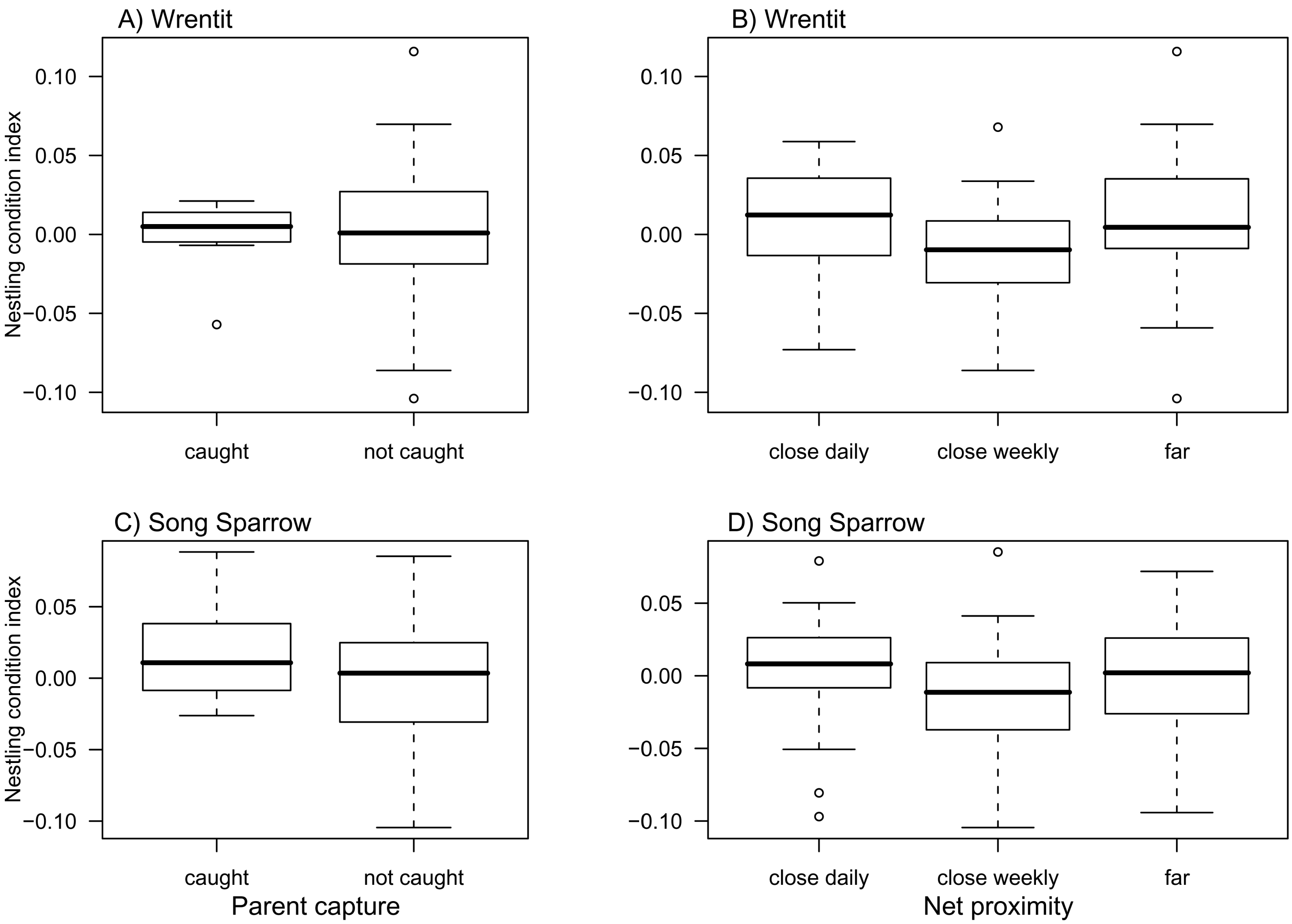

FIGURE 4. Condition index for nestlings from Wrentit and Song Sparrow nests in the parent-capture (A, C) and net-proximity (B, D) groups at the Palomarin Field Station, California, from 1982 to 2006. Box and whisker plots show the median (heavy line), 25th, and 75th percentiles (lower and upper margins of boxes, respectively). The ends of the whiskers indicate either 1.5 times the interquartile range (circles present) or the record farthest from the median (circles absent), whichever is smaller. Circles beyond the end of the whiskers represent records lying outside 1.5 times the interquartile range.

25 years, there was substantial turnover of individuals during the study, reducing the potential of repeated sampling of the same pairs contributing to the patterns we observed. We used only the first nest of each female recorded each year to account for changes in parental effort within a season (i.e., greater effort later in the season) and to reduce pseudoreplication resulting from sampling multiple nests of the same parents. We did not account for any changes in parental effort within nests resulting from partial predation because partial predation was relatively uncommon. We believe that the large number of nests in our study provided precision sufficient to outweigh the uncertainty caused by these limitations.

Because this study entailed direct measures of reproductive performance, it required greater human activity at nests than is typical at banding stations. Bird populations studied only with mist netting will experience less overall human activity, and the dynamics of mist-net operation and reproductive performance may be different from what we observed. Given that the combined effects of mist netting and nest monitoring that we observed were slight, one can reason that reproductive performance will be affected even less at study sites with mist netting only.

We paired our results with a thorough discussion of the limitations of our study so that readers may better understand our conclusions. We suggest this study provides a cautious, two-fold validation of the use of mist nets in ornithology. The first is scientific: a validation of the use of mist-net captures as an indicator of reproductive performance (Bollinger and Linder 1994, Gardali et al. 2000, Ralph and Dunn 2004). Our results provide no strong evidence that human activity associated with mist netting affects birds' reproductive performance. Further investigation may elucidate the pattern of increased survival of nests from which at least one parent is captured during the nesting cycle. The second validation is ethical: the indication that mist nets are a safe method for monitoring passerines during the breeding season. The lack of measured negative response to mist netting suggests that operating nets according to the protocol we used is unlikely to cause harm to bird populations by reducing reproductive success.

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