Research Note

Radiotransmitter Mount Type Affects Burrowing Owl Survival

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(JOURNAL OF WILDLIFE MANAGEMENT 70(3):872–876; 2006)

Key words

Athene cunicularia, *backpack harnesses, burrowing owl, California, radiocollars, radiotagging mortality, radiotransmitter effects, return rates, survival.*

Radio transmitters have greatly expanded our ability to study free-ranging wildlife and have led to a much greater understanding of their ecology, dispersal, and migration. Although transmitter weight continues to drop even as power increases, radiotagging an animal can have negative consequences for that individual, particularly for birds. Documented effects of radiotransmitters on birds include reduced survival (Burger et al. 1991, Paton et al. 1991, Cotter and Gratto 1995), reduced productivity (Paton et al. 1991, Gammoneley et al. 1994), altered time budgets (Hooge 1991, Pietz et al. 1993), altered migration timing (Ward and Flint 1995), and increased foraging trip time (Croll et al. 1993).

Despite the potential for negative effects, radiotelemetry remains one of the most powerful tools to explore aspects of behavior that may be extremely difficult to document otherwise. Burrowing owls (*Athene cunicularia*) typify a species whose relatively small size (ca. 150 g; Haug et al. 1993), nocturnal habits, and potentially great movement range (Haug and Oliphant 1990, Sissons et al. 2001, Gervais et al. 2003, Rosenberg and Haley 2004) require radiotelemetry for many research and management questions, despite the potential cost to the individuals carrying the transmitters. Previous work using radiotelemetry on the species failed to document radiotransmitter effects (Todd et al. 2003; Conway and Garcia 2005), or it did not report whether that was explored (Haug and Oliphant 1990, Sissons et al. 2001). In all of these cases, the migratory nature of these populations resulted in very low return rates, which may preclude detecting the survival costs of radiotagging. In addition, radiotagging of owls, as part of mitigation or simply to explore behavior, has been suggested in the absence of specific research hypotheses (J. A. Gervais, Oregon State University, personal observation). Such unstructured use of radio transmitters assumes that they have no effect on their subjects, and this assumption should be rigorously tested.

It is also very likely that some transmitter-mounting types are better than others. Two different mounting systems, harnesses and collars, have been used on burrowing owls with little evaluation of relative survival costs. This is in spite of the fact that harnesses in particular, have been associated with increased mortality even when other mounting techniques appear to have no effects (Hooge 1991, Garrettson et al. 2000, Withey et al. 2001). The one study that did compare harnesses with collars on burrowing owls deployed only 11 harnesses (Todd et al. 2003), making detection of effects highly unlikely.

We conducted research on the demographics, space use, and dispersal patterns in 2 resident populations of burrowing owls in California. We used 2 different radio attachment methods with varying total mass during the course of these research projects. We examine mark–resight data to test for possible effects of the radiotransmitters so that future research can more accurately assess the survival costs associated with using radiotelemetry on burrowing owls. Specifically, 1) Do radio collars or harnesses reduce the survival of burrowing owls relative to banded, but not radiotagged, control owls? 2) Do effects vary from year to year or by age or sex of the owl? 3) How does the risk of mortality relate to either time of season or time since tagging?

Study Area

We conducted research on burrowing owls using radiotransmitters at 2 sites in California, USA. Naval Air Station Lemoore (hereafter Lemoore) was located 50 km southwest of the city of Fresno in the San Joaquin Valley (36°18′N, 119°56′W). Owls at this site nested along runways and taxiways and in fallow fields. Most of the study area was taken up by intensive agriculture of cotton, alfalfa, tomatoes, and corn (Gervais et al. 2003).

The second study area was located on and adjacent to the Sonny Bono Salton Sea National Wildlife Refuge (hereafter Imperial Valley), near the city of El Centro in the Imperial Valley (33°1′N, 115°3′W), USA. This region supported year-round agricultural production. Owls nested along the water delivery and drainage systems bordering the agricultural fields (Rosenberg and Haley 2004).

Methods

At Lemoore, breeding adult male and recently fledged young owls were radiotracked from April to September in 1998 and 1999 for a

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study of foraging habitat selection (Gervais et al. 2003). At Imperial Valley, adult owls of both sexes were radiotracked throughout the year between April 2002 and April 2003 for a study examining dispersal movements following nest failure (Catlin 2004), and young were tracked to determine postfledging dispersal (D. H. Catlin and D. K. Rosenberg, Oregon State University, Corvallis, Ore., USA, unpublished data). Both study areas also included banding and resighting work to estimate survival rates of the larger populations. These banded owls were used as controls.

We attempted to identify every owl banded on the study site at Lemoore each spring during 1997–2001. We located owls through nest searches conducted along transects within all potential owl habitat as described in Gervais et al. (2003). Observers walked along transects so that all areas within 30 m were searched for potential burrowing owl nests. This method resulted in location of all nests (detection probability of 1.0) based on an estimate of detection probability from a sample of the study area (D. K. Rosenberg and J. A. Gervais, Corvallis, Ore., USA, Oregon State University, unpublished data). We observed all potential nests daily to once weekly, depending on location, to identify previously banded owls. At Imperial Valley, we used similar methods except that we located owls and potential nests through a series of surveys conducted by vehicle that resulted in recapture probabilities >0.9 (Rosenberg and Haley 2004). We used naive observers to relocate owls to avoid search bias based on prior knowledge of locations of radio-tagged owls. Owls included in the radiotelemetry study were banded in 2002 and relocated in 2003.

Owls were captured using a variety of methods, including 2-way burrow traps and bow nets (Gervais et al. 2003, Rosenberg and Haley 2004). All captured owls were banded with an aluminum, alphanumeric, color band (Acraft Sign and Nameplate Co., Ltd., Edmonton, Alberta, Canada) and a nonlocking No. 4 U.S. Fish and Wildlife Service band. We assigned gender to adults based on presence/absence of brood patch, plumage coloration, and behavioral observations (Haug et al. 1993).

Selection of owls to be radiotagged varied by site. At Lemoore, we targeted all adult male owls that had initiated nesting for radiocollars, and we made a particular effort to trap and mark owls from all parts of the study area and that were associated with nests sampled for toxicological work (Gervais and Anthony 2003, Gervais et al. 2003). We did not capture all males, and males that had been previously banded served as controls. With 2 exceptions, we randomly chose juvenile owls from among all those caught at a nest that were >120 g or whose wing chords were >120 cm and were >3 weeks of age. This ensured that owlets were strong enough and coordinated enough to avoid entanglement in the radiocollar. Nests at Imperial Valley were selected for inclusion in a study of dispersal behavior (Catlin 2004). Adults at each study nest were trapped and radiotagged if possible. When captured, juveniles that weighed >120 g from nests used in the dispersal study were also radiotagged. Nonradioed juveniles used in the analyses for both sites were restricted to the same range of mass as the radiotagged juveniles to avoid bias.

We used 2 different transmitter mounting systems of varying mass. At Lemoore, we used prefitted, necklace-style collars weighing between 3.6 and 4.5 g, depending on battery life (Model PD-2C, Holohil Systems Ltd., Ontario, Canada). These were specifically designed for burrowing owls. We used the second type of transmitter mounting system at Imperial Valley in 2002–2003. The Imperial Valley study required much greater battery life and range because of the study's duration and the need to locate dispersing individuals. These radios (American Wildlife Enterprises, Monticello, Florida) were backpacks with loops of Teflon ribbon encircling the wings and were fastened together at the breast. The total package weighed an average of 5.1 g (SE $= 0.02$ g, $n = 36$, range $= 4.7$–5.3 g).

We estimated the proportions of owls returning to the study area in the year following radio-tagging for each age class and radio group. We radiotagged 3 adult males at Lemoore in both 1998 and 1999; they were included in both years as independent samples because we assumed that survival during the second year of carrying a radio was not influenced by the previous year. We used the methods of Fleiss (1981:14) to calculate 90% confidence intervals. Our use of return rates as a relative measure of survival assumes the presence of a radio did not affect resight or recapture probability (sensu Skalski and Robson 1992). We tested this assumption for Lemoore by estimating recapture probabilities of radiocollared and control owls (banded, but without radios) using modified Cormack–Jolly–Seber models in Program MARK (White and Burnham 1999). Specifically, we added a radio effect on recapture probabilities for 1998 radioed owls, 1999 radioed owls, or both groups to a series of models estimating survival rates. We report recapture probabilities based on the estimate from the best of these 3 models. Data from Imperial Valley were insufficient in duration to test this assumption.

In addition to estimates of annual return rates at Imperial Valley, we estimated temporal patterns of mortality of radiotagged individuals at Imperial Valley on a weekly timescale. These estimates were based solely on radiotagged owls. We performed weekly or biweekly searches from April 2002–April 2003 to determine the location and status (alive or dead) of each radio-tagged individual. Additional aerial searches were performed for owls that were not located by ground surveys (Catlin 2004). These search methods resulted in the relocation of all but 1 adult owl (98% detection rate) and 3 juvenile owls (91% detection rate).

Among radio-tagged individuals, we hypothesized that the influence of radio harnesses on mortality should decrease with the number of days since an individual was harnessed as owls acclimatized to the harnesses or died. Furthermore, we hypothesized that the effect of number of days since tagging should be higher early in the study if there was a handling effect that lessened as biologists improved their ability to harness owls during the study. We used a counting process formulation (Anderson and Gill 1982) of the Cox proportional-hazards model (Cox 1972) to evaluate the effects of the number of days since an owl received a transmitter while controlling for Julian date. Individual birds entered the risk set on the day they were fitted with a radio transmitter. The baseline hazard function was related to Julian date, whereas days-since-tagging (modeled as days-since-tagging * Julian date interaction) and gender were entered as covariates in the model. We treated days-since-tagging and its interaction with Julian date as time-dependent covariates, and we square root–transformed days-since-tagging to reduce skewness to which the

Cox model is sensitive (S-PLUS 2001). We used the covariates gender, days-since-tagging, and an interaction between days-since-tagging and Julian date. This analysis was performed only for adult owls because the small sample of juvenile owls prohibited an evaluation of the interaction between days-since-tagging and Julian date.

Results

We fitted 110 owls at Lemoore with radio collars during 1998 and 1999, and another 224 owls were banded but not radiocollared and included in the return rates analysis (Table 1). The minimum mass of juvenile owls included in our analysis was 108 g; only 2 radiocollared juveniles were under 120 g (108 and 112 g, respectively). Patterns of effects were consistent across age classes and years despite the lack of precision in the point estimates. The relative difference in return rates between control and radiotagged owls was similar in juveniles and adults; the lack of precision in the estimates resulted in inconclusive effects (Table 1). During 1999–2000, these differences were greater, although still imprecise, suggesting potentially strong effects (Table 1).

We assumed similar recapture probabilities between owls with and without radios to treat estimates of return rates as an index of survival. Recapture probabilities of adult males were almost identical between owls with radios ($\bar{x} \pm$ SE: 0.68 $\pm$ 0.18, $n = 47$) and those without (0.70 $\pm$ 0.12, $n = 40$). In both years, there was little evidence of a difference in recapture probability between juveniles with and without radios (1998, no radio: 0.71 $\pm$ 0.13, $n = 47$, radio: 0.66 $\pm$ 0.20, $n = 28$; 1999 no radio: 0.89 $\pm$ 014, $n = 132$, radio: 0.76 $\pm$ 0.20, $n = 32$).

We fitted and monitored 59 (37 female, 22 male) adult owls and 34 juvenile owls with radio harnesses at Imperial Valley during 2002, and another 67 adults of known sex and 8 juveniles were banded but not radioharnessed. We observed strong radio effects on return rates at Imperial Valley for adult owls. Return rates for adult radioharnessed owls were approximately half that of owls without radio harnesses (males: 6 of 22, 0.27 [90% CI: 0.13–0.46] vs. 23 of 38, 0.61 [90% CI: 0.46–0.74]; females: 9 of 37, 0.24 [0.14–0.38] vs. 14 of 29, 0.48 [90% CI: 0.31–0.66]). Of 34 radioharnessed young, 15 (44.1%) were known to have died during the summer of 2002, and most of the remaining were found dead in the fall and winter. None were seen alive in 2003 within the study area. There were only 8 nonradioharnessed fledglings banded. None were known to have died during the summer, and 2 (25%) were seen alive as adults in 2003.

Temporal patterns of mortality of radio-harnessed owls suggested that radio harnesses had the greatest effect soon after tagging (Fig. 1). Of the individuals that were known to have died, 28 of 41 (68.3%) adults and 20 of 29 (69.0%) juveniles died within the first 15 weeks following radio-tagging. Of the carcasses recovered soon after death, the identifiable proximate cause of mortality was predation.

The survival of adult radioharnessed owls appeared to be affected both by days-since-tagging and by gender. Of the 59 radio-harnessed owls (37 female, 22 male), 17 survived the duration of the study (11 females, 6 males). The multiplicative decrease associated with later tagging dates (square root of days-since-tagging * Julian date: 0.998, 90% CI: 0.996–0.999) and increased time since tagging (square root of days-since-tagging: 0.88, 90% CI : 0.71–1.09) indicate that the risk of mortality decreased through the period and did so more quickly for those owls harnessed later in the season. In addition, female owls appeared to have a much lower risk than male owls when time-since-tagging and the interaction with Julian day were held constant; their risk of mortality was nearly half that of male owls (0.49, 90% CI: 0.27–0.89).

Discussion

Burrowing owl survival was negatively affected by radiotransmitters regardless of mounting method, and this pattern was consistent across age classes, sites, and years. The effects were very clear when transmitters were attached using harnesses. Adult owls fitted with radioharnesses returned at a rate half that of banded controls, with the greatest mortality occurring within the first few weeks following transmitter deployment. There appeared to be sex-specific differences, with male owls at greater risk of mortality than females. Thus, all 3 of our hypotheses were upheld for the effects of radiotransmitters mounted with harnesses.

For radiocollars, effects varied by year and were more prevalent in adult males than juveniles, but the effects were less clear because of poor precision and the resulting broad confidence intervals. However, the attachment method clearly can influence the likelihood of effects caused by radiotagging. Backpack transmitters mounted with harnesses on birds were generally associated with more negative effects than other types of mounts, although only 2 of 6 studies reported negative effects on raptors (Withey et al. 2001). Given the very small difference in mass between the 2 mounting methods we employed, we believe that it is the physical presence of the harness that leads to altered behavior and lowered survival.

Our results differ from the 2 other published studies evaluating transmitter effects on burrowing owls. Conway and Garcia (2005) detected no difference in the survival of juvenile owls following

Table 1. Comparison of return rates of radiocollared and noncollared burrowing owls at Naval Air Station Lemoore, Calif., USA, 1998–2000.

		Return rates					
		1998–1999			1999–2000		
Age–sex class	**Collared or not**	***n***	**%**	**Range**	***n***	**%**	**Range**
Adult males	Noncollared	21	0.52	0.33–0.71	26	0.23	0.11–0.40
	Radiocollared	26	0.35	0.20–0.52	24	0.08	0.02–0.23
Juveniles	Noncollared	47	0.36	0.25–0.49	130	0.11	0.07–0.16
	Radiocollared	28	0.21	0.10–0.38	32	0.06	0.01–0.18

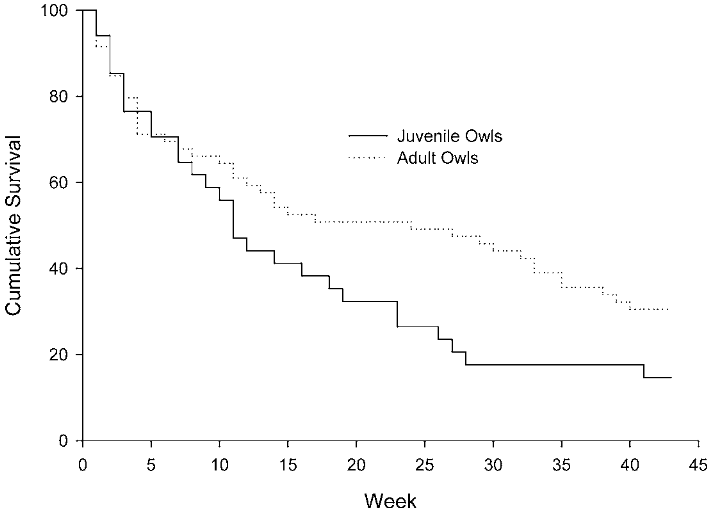

Figure 1. Cumulative survival of radioharnessed adult and juvenile burrowing owls at Imperial Valley, Calif., USA, 2002–2003. At week 1, there were 60 adults and 34 juvenile owls.

radiocollaring, but the very small sample sizes of returns of either collared or banded owls ($n = 7$ returned radiocollared juveniles of 174 radiocollared and $n = 21$ banded juveniles returned of 241 marked) makes effects nearly impossible to detect. Todd et al. (2003) did not detect effects when they tested for differences between harnessed and collared juveniles during the premigratory, postfledging period. The comparison between harnesses and collars was based on a very small sample size of 11 radioharnessed owls, and there were no estimates for survival for nonradioed, banded juveniles because of the impossibility of resighting them (Todd et al. 2003). Effects will be extremely difficult to detect in such cases unless they are particularly severe.

We believe that the mounting system, rather than transmitter mass, contributed to the substantial mortality at Imperial Valley. The harness-mount package weighed only 0.6 g more than the radiocollar package, which represents an increase of just 0.4% of body mass of an adult owl. Although this could also be explained if there is a threshold effect of increasing mass, it seems more likely that the additional mortality was caused by disrupted patterns of owl behavior. Many of the radioharnessed owls were observed biting at the harnesses and preening, and the most frequent known cause of death was predation. Owls distracted by harnesses will not be as vigilant, and perhaps not as responsive to the needs of their young, as owls without transmitters.

Our findings of an effect of number of days since radio-tagging on relative risk of mortality to adults in Imperial Valley is consistent with the hypothesis that owls that are disturbed by the presence of a radio harness are more likely affected soon after harnessing. Another reason why effects were strongest early in the study might be that field workers who harnessed the owls became more familiar with the technique on a particular species as the study progressed.

We found stronger effects on return rates of radiocollared owls in 1999–2000, which coincided with a population crash of a major prey species, the California vole (*Microtus californicus*). This resulted in reduced numbers of voles in the owls' diets (Gervais and Anthony 2003). Other studies have also documented that effects of radio transmitters may vary by year (Cotter and Gratto 1995, Ward and Flint 1995).

If behavioral response to the transmitter is the deciding factor in determining whether an owl is likely to suffer mortality from a radioharness or collar, it will be impossible to predict a priori which individuals are poor candidates for radiotagging. Therefore, the risk of mortality overall cannot be reduced by identifying high-risk birds and eliminating them from the radio sample. Although we observed owls that seemed to be less able than others to adjust to the radio packages, in our experience, it was extremely difficult to recapture these individuals to remove the package. Researchers cannot assume that negative impacts can be lessened by recapturing individuals unable to adjust to the transmitter packages.

Management Implications

Radiocollars appear to have effects on survival of burrowing owls in at least some years, but harnesses should be avoided because their effects can be severe. Training in fitting harnesses will be necessary for minimizing harness effects, but it is unlikely that this would be sufficient to eliminate the substantial negative impacts on the owls.

Acknowledgments

This work was supported by grants from the United States Navy Engineering Field Activities West, Bureau of Land Management Bakersfield Field Office, National Fish and Wildlife Foundation, the United States Geological Survey Cooperative Research Units, and California Department of Fish and Game. Logistical support was also provided by the Sonny Bono Salton Sea National Wildlife Refuge. Our research was supported in part by the Utah Agricultural Experiment Station, Utah State University, Logan, USA, approved as journal paper 7706. Our thanks especially to J. Crane of Naval Air Station Lemoore, J. Govan of United States Fish and Wildlife Service, A. Kalin of Kalin Farms, and A. Kuritsubo of Bureau of Land Management, and to C. Winchell of United States Fish and Wildlife Service, M. Abright, M. Anderman, M. Bond, C. Bailey, C. Dalton, V. Franke, T. Lanman, J. Podulka, and S. Solomon at Naval Air Station Lemoore and K. Haley, D. LaFever, D. Mitchell, H. Ober, and L. Robinson at Imperial Valley for providing invaluable field assistance.

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