Techniques and Technology Article

Effects of Radiotransmitter Necklaces on Behaviors of Adult Male Western Burrowing Owls

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ABSTRACT We studied the behavioral effects of necklace-style radiotransmitters on breeding male western burrowing owls (*Athene cunicularia hypugaea*) in 2 areas of northwestern Texas, USA, in 2004 and 2005. We tested the hypothesis that transmittered owls would spend time interacting with their necklaces and as a result spend less time in vigilance and resting activities than would nontransmittered owls. Nontransmittered owls ($n = 6$) spent significantly more time being vigilant ($P = 0.007$) than did transmittered owls ($n = 3$) in 2004, who spent significant amounts of time interacting with their necklaces. In 2005, behaviors of transmittered owls ($n = 8$) were significantly different ($P < 0.001$) from control individuals ($n = 4$), but behaviors did not vary consistently by treatment period (prenecklace vs. necklace vs. postnecklace periods). Behavioral activity budgets varied considerably among individuals. Although the owls spent a significant amount of time interacting with their necklaces, they appeared to habituate to the presence of the transmitters within a relatively short period (<1 week), and necklaces did not affect survivorship or fitness in the short-term. (JOURNAL OF WILDLIFE MANAGEMENT 71(5):1662–1668; 2007)

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KEY WORDS *Athene cunicularia hypugaea*, behavior, burrowing owl, radiotelemetry, Texas, transmitter attachment.

Radiotelemetry has been a widely used technique to study habitat selection and dispersal in animals, including the burrowing owl (*Athene cunicularia*). Researchers have used necklace-style (collar) transmitters (Haug and Oliphant 1990, Leupin and Low 2001, Sissons et al. 2001, Gervais et al. 2003, Rosier et al. 2006) and backpack (harness) transmitters (Catlin 2004) on adult burrowing owls. Both transmitter types have also been used in studies of juvenile burrowing owl dispersal and associated mortality (Clayton and Schmutz 1999, King and Belthoff 2001, Todd 2001, Todd et al. 2003, Conway and Garcia 2005).

Examinations of the physical effects of radiotransmitters on condition, survival, or fitness of burrowing owls have yielded equivocal results. During a 4-year study, Todd et al. (2003) noted that neither necklaces nor backpacks affected short-term survivorship (i.e., survival within a single breeding season) or caused physical effects (e.g., abrasions, feather loss, changes in mass). Clayton and Schmutz (1999) similarly concluded that necklaces did not affect short-term survivorship. However, Rosier et al. (2006) found evidence of reduced short-term survivorship in owls with necklaces; a similar effect with backpacks was noted by Catlin (2004) within a single breeding season. Over a longer term, annual return rates were lower for transmittered owls in California, USA, than for those without necklaces (Gervais et al. 2006). Backpacks were associated with even higher mortality, so much so that Gervais et al. (2006) recommended avoiding the use of backpacks on burrowing owls. However, the higher mortality occurred only during a low-food year and not during other years, so it is possible that transmitters induce effects only during periods of stress.

Given the possibility of physical responses by burrowing owls to radiotransmitters, it is likely that owl behaviors may also be affected (Conway and Garcia 2005). However, behavioral effects of transmitters on burrowing owls have not been previously studied. During the initiation of a telemetry study of burrowing owls (Chipman 2006), we observed apparent distress by individual owls following attachment of necklaces. Given this, we suspected that an owl's activity may be influenced by the presence of a necklace-style transmitter. The 4.55-g Model PD-2C necklace from Holohil Systems Ltd. (Carp, ON, Canada) was approximately 3% of the adult male burrowing owl's average body weight of 150 g in the southern Great Plains, USA (Teaschner 2005), which was less than the maximum recommendation of transmitter weights being <5% of a bird's body weight.

Given our initial observations and that telemetry is frequently used on this species of international conservation concern, we investigated the behavioral effects of necklace transmitters on burrowing owls. Our goal was to compare activity budgets of owls with and without necklaces to determine whether behaviors were affected and, if so, whether the owls became habituated to the necklaces.

STUDY AREA

Research was conducted in Lubbock (2 sites) and Carson (1 site) counties, Texas, USA, in 2004 and 2005; we used 2 sites each year (1 Lubbock and 1 Carson site in 2004, 2 Lubbock sites in 2005). All sites were associated with black-tailed prairie dog (*Cynomys ludovicianus*) colonies, upon

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whose burrows the burrowing owl is highly dependent in the Great Plains. In 2004, one of the 2 study sites was located within the city limits of Lubbock; the other was in Carson county on the Pantex Plant (hereafter, Pantex), a United States Department of Energy National Nuclear Security Administration facility. In 2005, we used the 2004 Lubbock site and an additional site within the Lubbock city limits. All sites were similar in terms of topography, indigenous habitat, and climate. The terrain was flat and relatively constant, with elevation ranging from approximately 1,000 m to 1,036 m. The native habitat of the region is shortgrass prairie, consisting of grassland with little woody vegetation. Average air temperatures during the period of study ranged from highs of 33–34° C and lows of 19–21° C, and the area receives 47–50 cm of precipitation annually (5–9 cm during the period of study). Detailed descriptions of the study sites may be found in Chipman (2006).

METHODS

Experimental Design and Data Collection

We used a paired treatment–control focal-animal design in 2004 to compare simultaneously the behaviors of transmittered owls to those of nontransmittered individuals. Owl capture and data collection occurred during 5–14 June 2004. For each site, we monitored 2 pairs of males simultaneously, each consisting of one transmittered and one control (nontransmittered) individual.

The necklace transmitter consisted of an elasticized band with an elastic core and a webbed-fabric exterior sheath that limited the stretch of the elastic, a 12-cm wire whip antenna that emerged from the back, and transmitter electronics housed within a smooth, kidney-bean-sized nodule. When placed on an owl, the nodule was located in the front (like a necklace) and the antenna emerged from the nape. The weight of the transmitter was, thus, greatest at the owl's throat, which is an area that naturally experiences variable weights according to prey consumption (Amstrup 1980). However, to ensure that swallowing of large prey was not hindered, the necklace was placed on loosely enough that it could rotate completely around the bird's neck. Each necklace was knotted at a specific diameter (2.8 cm) before placement on the owl, which was done by placing the necklace on a cardboard toilet-paper tube, placing the tube over the owl's head, and slipping the necklace off the tube and around the owl's neck. The band was knotted when the elastic was not fully extended, allowing some stretch to the necklace. The necklace's circumference was 11 cm, the size recommended by Holohil based upon previous burrowing owl telemetry studies (J. Edwards, Holohil Systems Ltd., personal communication). When the necklace was placed over the toilet-paper tube, it was at its maximum stretch, which should have allowed the necklace to be loose enough not to choke the owl and to move freely around the neck.

For 3 days prior to capture (prenecklace period), we observed each owl to quantify normal activity budgets. On day 4, we captured the male owls at their burrows with bal-chatri traps, noose carpets, or bow nets (Hull and Bloom 2001). We morphometrically measured all captured owls, banded each with a size-4 United States Geologic Survey Bird Banding Laboratory (Patuxent, MD) band on one leg, and uniquely marked each with a red Acraft (Edmonton, AB, Canada) alpha-numeric coded aluminum band on the other leg. The combined weight of both bands was approximately 2 g. One male of each observation pairing also received a 4.55-g Holohil PD-2C necklace transmitter with a 24-week battery lifespan (Texas Tech University Animal Care and Use Committee permit no. 03079-11C to N. E. McIntyre). We did not place transmitters on the remainder of captured owls, although one of these owls was monitored as a treatment individual during the prenecklace period and the remainder served as controls. We closed the necklace with a knot that we coated (in 2004) with Loctite Super Glue (Henkel Consumer Adhesives, Inc., Avon, OH) or (in 2005) with cold-weld (J-B Weld, Sulphur Springs, TX). Unlike the Super Glue, the cold-weld formed a smooth surface with no purchase for an owl's beak or talons. Following transmitter attachment, we monitored all owls (necklace period) until day 10, when we recaptured, reweighed, and removed transmitters on some.

For each observation period, 2 people simultaneously monitored a treatment–control pair (one observer for one owl with a necklace and one observer for one control owl). For each owl, we noted 1 of 6 mutually exclusive positions: in burrow, out-of-sight on the prairie dog colony (i.e., obscured by vegetation), out-of-sight off the prairie dog colony (after we observed the owl flying beyond the colony boundaries), standing alert on ground, perching above the ground, or flying. For the last 3 positions, we then determined activities (e.g., preening, hunting, etc.). Because we were more concerned with behavioral activities than with locations, we statistically analyzed activity rather than position (Table 1). For example, if an owl was hunting while flying (e.g., hovering, hawking, or swooping) as opposed to flying from one place to another directly, we designated the behavior as hunting. In addition, we defined hunting on the basis of behavior, not outcome (i.e., hunting did not always result in successful prey capture). We designated resting when all other behaviors could be eliminated. Using this hierarchical system rather than partitioning behaviors on the basis of both activity and position such as preening on ground versus preening on perch maximized statistical power to detect patterns among the actual activities of interest (Lehner 1996).

We monitored owls with binoculars and 15–45× spotting scopes, using vehicles as observation blinds at an average distance of 50 m (range: 12–200 m). We recorded behaviors for each owl at 1-minute intervals in 2-hour blocks of time between 0630 hours and 2030 hours. We randomly chose one 2-hour block of time each day for observations during the 7-day treatment period.

In 2005, we added a postnecklace period to the study design; thus, in 2005 there was a 5-day prenecklace period, a 5-day necklace period, and a 5-day postnecklace period. In addition, we attempted to boost sample size in 2005 by

Table 1. Definitions of burrowing owl behavioral categories used in Lubbock and Carson counties, Texas, USA, in 2004–2005. All owl activities were categorized into 13 behaviors: 6 are mutually exclusive positions and 7 are mutually exclusive behaviors.

Position	Definition	
In burrow	Inside nesting burrow or any burrow	
Out-of-sight on colony	Out of sight on prairie dog colony but not in burrow	
Out-of-sight off colony	Out of sight off prairie dog colony	
Vigilance	Standing on ground, eyes open, alert	
Perching	Perching on object above ground	
Flying	Flying from one place to another but not engaged in hunting, aggression, or defense	
Behavior	**Definition**	**Behavioral Hierarchy**
Rest	Resting, relaxed (eyes closed or a foot raised)	If rest and perch, then perch
Preen	Preening	If preen and perch, then preen
Hunt	Actively scanning by turning head, hovering, flycatching (hawking), or swooping; may or may not result in prey capture	
Eat	Eating	
Feed	Provisioning mate or owlets	
Chew	Interacting with radiocollar (chewing, footing, rolling head)	If chew and perch, then chew
Other	Any other behavior not listed	

capturing as many males as possible at 2 sites in Lubbock, resulting in 6 owls with necklaces at one site and 2 owls at the other. We also omitted the paired-owl design in an attempt to observe as many transmittered owls per site as possible. This allowed a focus on only transmittered birds. Furthermore, because owl activity was affected by time of day in 2004 (diminished activity at midday), observations in 2005 were limited to morning and late afternoon and evening, with individual owls monitored in a particular 2-hour block of time instead of a randomly chosen block as in 2004. Owl capture and data collection occurred from 30 May to 24 June 2005.

Statistical Analyses

We used SAS 9.1 (Cary, NC) to analyze the data with multivariate analysis of covariance (using Wilks' λ) followed by individual analyses of covariance (ANCOVA) and then Tukey's Honestly Significant Difference Test for all significant ($P \leq 0.05$) results. We used site, treatment period (for 2004: prenecklace, necklace periods; for 2005: prenecklace, necklace, postnecklace periods), owl identity, and treatment (transmittered or control) as the fixed main effects. We used total minutes of observation, number of owlets, and time of day as covariates. For site comparisons, we used the sequential sums of squares (Type I). We analyzed data from 2004 and 2005 separately due to the change in methods for 2005.

RESULTS

We captured 9 owls in 2004; 3 of these were transmittered and 6 served as controls. We omitted one owl that was transmittered in 2004 from analysis because it was not the same individual that was monitored prior to receiving a necklace. We captured 12 owls in 2005; 8 were transmittered and 4 served as controls.

Recapture of all owls with necklaces for transmitter removal was not possible in 2005, as 4 individuals were too trap-shy to be recaptured. We omitted these trap-shy owls from postnecklace analyses but we examined them to determine longer-term effects of the transmitter throughout the breeding season. One of these individuals chewed through the elasticized band and removed his necklace after 24 days; another pulled the antenna out after 30 days and was not relocated.

In both years, transmittered owls interacted with their necklaces, but interactions decreased over time (Figs. 1, 2). Owls that could not be recaptured for necklace removal showed a similar habituation (Fig. 3).

In 2004, treatment period (prenecklace vs. necklace periods; $F_{12} = 2.88$, $P = 0.007$) and treatment ($F_{12} = 2.30$, $P = 0.027$) were significant determinants of owl behavior. Number of owlets ($F_{24} = 1.73$, $P = 0.040$) was a significant covariate, but neither ANCOVA nor Tukey's post hoc tests revealed any trends in behavior with number of owlets (Table 2). For treatment period, vigilance ($F_1 = 8.96$, $P = 0.004$), preening ($F_1 = 12.55$, $P = 0.001$), eating ($F_1 = 5.63$, $P = 0.022$) and "other" ($F_1 = 5.40$, $P = 0.024$) behaviors were performed more in the prenecklace period (Fig. 4). For treatment versus control, nontransmittered owls displayed

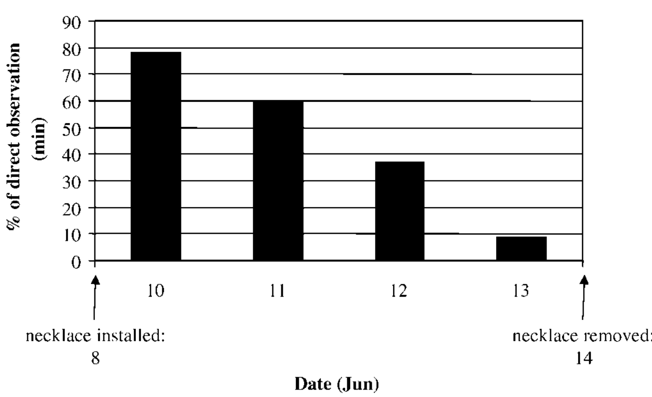

Figure 1. Example of burrowing owl habituation to necklace: owl L2 percentage of total observation minutes spent in necklace interaction during a 4-day necklace period in Lubbock, Texas, USA, in 2004.

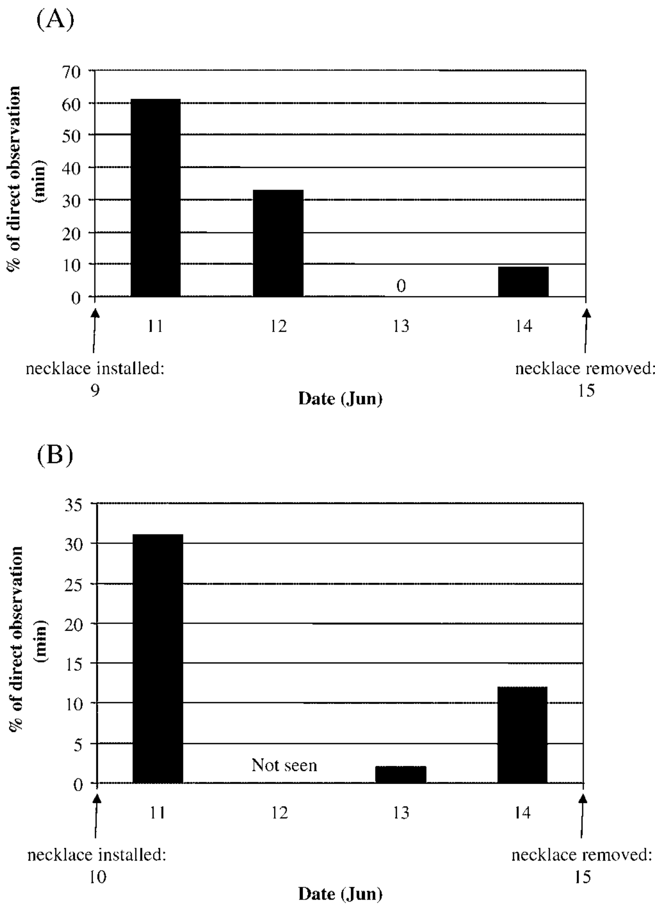

Figure 2. Examples of burrowing owl habituation to necklace: percentage of total observation minutes spent in necklace interaction during necklace period (4 d) in Carson County, Texas, USA, in 2004 for (A) owl P4 and (B) owl P5. P4 was not observed to interact with its necklace on 13 June, and P5 was not seen at all on 12 June.

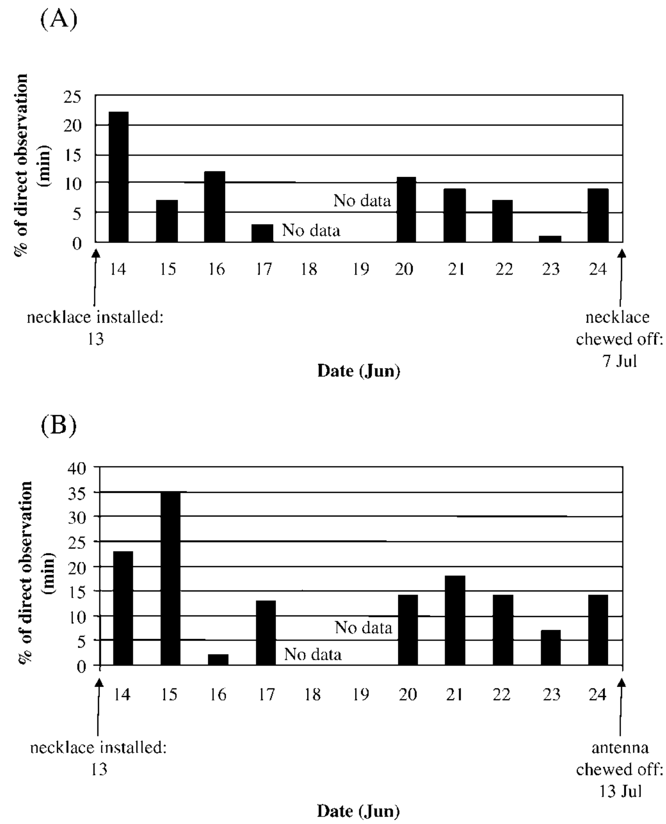

Figure 3. Examples of burrowing owl habituation to necklace: percentage of total observation minutes spent in necklace interaction in Lubbock, Texas, USA, in 2005 for (A) owl DSB and (B) DSD. Neither owl was observed on days stating "No data." Neither could be recaptured for necklace removal and, thus, are not included in postnecklace behavior analysis.

greater vigilance ($F_1 = 4.33$, $P = 0.043$), and transmittered owls exhibited greater "other" ($F_1 = 7.00$, $P = 0.011$) behaviors (Fig. 5).

In 2005, treatment period (prenecklace vs. necklace vs. postnecklace periods; $F_{24} = 5.32$, $P < 0.001$) affected amount of time in vigilance ($F_2 = 8.12$, $P = 0.001$), resting ($F_2 = 4.02$, $P = 0.021$), preening ($F_2 = 4.05$, $P = 0.020$), perching ($F_2 = 4.60$, $P = 0.012$), hunting ($F_2 = 7.40$, $P = 0.001$), eating ($F_2 = 4.88$, $P = 0.009$), and flying ($F_2 = 3.83$, $P = 0.025$). However, Tukey's post hoc tests were unable to reveal trends by period for resting, perching, and eating. Owl identity was nonsignificant, meaning that certain owls did not consistently engage in certain behaviors ($F_{48} = 1.06$, $P > 0.05$; Table 2). Number of owlets ($F_{48} = 1.67$, $P = 0.005$) was a significant covariate: amount of time spent hunting ($F_1 = 15.89$, $P < 0.001$) and feeding ($F_1 = 15.61$, $P < 0.001$) were affected by the number of owlets being provisioned by the male, but again there were no consistent trends (i.e., M with more owlets did not consistently hunt more than M with fewer offspring). Vigilance ($F_1 = 10.48$, $P = 0.002$), eating ($F_1 = 6.10$, $P = 0.015$), feeding ($F_1 = 4.32$, $P = 0.040$) and flying ($F_1 = 10.27$, $P = 0.002$) differed among sites, although we were unable to identify any significant trends with Tukey's post hoc tests.

In terms of effects on owl survival and productivity, none of our study owls (either transmittered or not), their mates,

Table 2. Significant (multivariate analysis of covariance [MANCOVA], individual analysis of covariance [ANCOVA], Tukey's Honestly Significant Difference Test; $P \leq 0.05$) variables affecting burrowing owl behaviors, Texas, USA, 2004–2005. "NS" indicates nonsignificance and "NA" indicates nonapplicable; $n = 9$ owls in 2004 and $n = 12$ in 2005.

Fixed main effect	2004	2005
Site	NA	[a]
Treatment period	$F_{12} = 2.88$, $P = 0.007$	$F_{24} = 5.32$, $P < 0.001$[a]
Owl identity	NA	NS
Treatment or control	$F_{12} = 2.30$, $P = 0.027$	NA
Covariate	**2004**	**2005**
Total min of observation	NA	$F_{120} = 2.63$, $P < 0.001$
No. of owlets	$F_{24} = 1.73$, $P = 0.040$[b]	$F_{48} = 1.67$, $P = 0.005$
Time of d	NA	NA

[a] Results significant in MANCOVA and ANCOVA but not in Tukey's post hoc tests.
[b] Result significant in MANCOVA but not in ANCOVA or Tukey's post hoc tests.

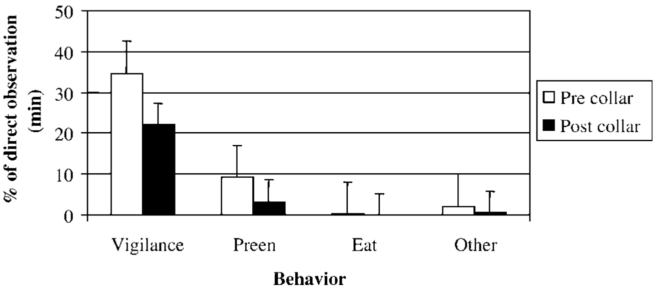

Figure 4. Significantly different behaviors of burrowing owls ($\bar{x}$ + SE) in prenecklace (41.37 hr of observations) versus postnecklace (57 hr) in Lubbock and Carson counties, Texas, USA, in 2004.

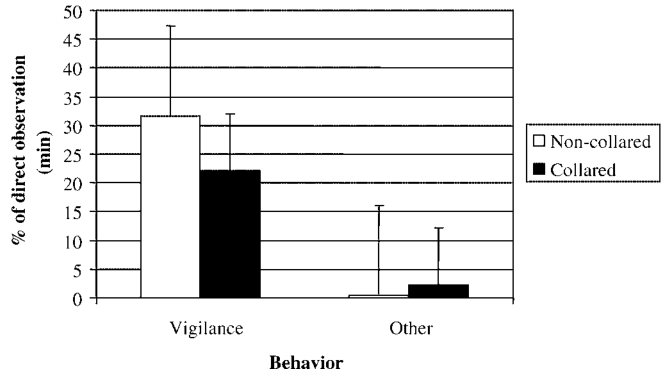

Figure 5. Significantly different behaviors ($\bar{x}$ + SE) in nontransmittered (53.37 hr of observations) versus transmittered (45 hr) burrowing owls in Lubbock and Carson counties, Texas, USA, in 2004.

or their chicks died during our study, and no nests were abandoned during either summer.

DISCUSSION

A key assumption in telemetry studies is that the animal is unaffected by the presence of the transmitter and behaves and survives as though untransmittered (White and Garrott 1990). However, there are a number of studies that have documented effects on a variety of avian taxa, particularly Galliformes and Anseriformes (Conway and Garcia 2005). We found that although owls interacted with their necklaces, this effect diminished over time, no mortalities occurred, and no nests were abandoned due to the transmitters.

Different methods of transmitter attachment have elicited different effects on various avian species (Tables 3, 4). For burrowing owls, necklaces are easier to install and, therefore, involve less handling time than do backpack-style transmitters, which must be specifically adjusted to the individual (Kenward 2001). There are more physical contact points of the backpack with the owl as well, due to the harness straps, which may damage feathers under the backpack transmitter. Backpack antennas remain clear of the front of the bird, unlike necklaces, which freely rotate around the neck. Sissons et al. (2001) noted that the necklace design predisposes the antenna to removal attempts by the owl. Indeed, we noted physical damage made by the owls on most of the transmitters we used, and one burrowing owl removed the antenna entirely within a 30-day span. In terms of physical effects as a result of the necklace, one of our owls developed a mild callus on the nape that was visible upon removal of the necklace.

The use of transmitters may increase the risk of predation on individuals preoccupied with backpacks or necklaces

Table 3. Summary of studies on effects of backpack and necklace transmitters on various avian species. The "↓" arrow indicates a decrease in the particular effect, and "↑" indicates an increase.

Citation	Species[a]	Minimal – no effect	Negative effect
Backpacks			
Brander 1968	Ruffed grouse	No effect	
Neudorf and Pitcher 1997	Hooded warbler	No effect on provisioning of young	
Hines and Zwickel 1985	Blue grouse	No effect on behavior, survival, or reproduction	
Boag 1972	Red grouse		↓ activity and food consumption
Johnson and Berner 1980	Ring-necked pheasant		↓ Wt gain and survival
Ward and Flint 1995	Brant		↓ Migration return rates
Ramakka 1972	American woodcock		↓ Courtship and dominance behaviors
Paton et al. 1991	Spotted owl		↓ Survival and reproductive rates
Foster et al. 1992	Spotted owl		↓ Productivity
Greenwood and Sargeant 1973	Mallard, blue-winged teal		↓ Swimming, ↑ feather loss and skin irritation
Perry 1981	Canvasback		Extended transmitter interaction, ↓ food consumption and wt
Necklaces			
Citation	**Species[a]**	**Minimal – no effect**	**Negative effect**
Gilson 1998	Osprey	Minor annoyance behavior	
Hernández et al. 2004	Northern bobwhite	No effect on body mass, food consumption, or energy	
Schmutz and Morse 2000	Emperor goose		↓ Breeding propensity
Sorenson 1989	Redhead		↑ Preening and ↓ breeding behaviors
Bro et al. 1999	Gray partridge		Variance in survival, reproduction, and body mass

[a] Scientific names are listed in Appendix.

Table 4. Summary of studies comparing various types of radiotransmitters on various avian species. The "↓" arrow indicates a decrease in the effect, and "↑" indicates an increase.

Transmitter types	Citation	Species[a]	Effect
Poncho and backpack	Small and Rusch 1985	Ruffed grouse	Recommended ponchos
Poncho and backpack	Pekins 1988	Blue grouse	Recommended ponchos
Poncho and backpack	Carroll 1990	Gray partridge	Both types ↓ survival
Poncho and backpack	Cotter and Gratto 1995	Rock ptarmigan	Both types ↓ survival
Necklace and backpack	Marcström et al. 1989	Ring-necked pheasant	Recommended necklaces
Backpack and breast-mount	Osborne et al. 1997	Northern bobwhite	Both types ↓ body mass and survival
Backpack and tail-mount	Reynolds et al. 2005	Northern goshawk	Tail-mounts ↓ survival

[a] Scientific names are listed in Appendix.

(Amstrup 1980, Sorenson 1989, Foster et al. 1992). We observed one owl that flopped around on the ground with wings held out while pulling at the necklace, and another was observed flapping its wings and hopping on one foot while yanking the antenna with the other. Burrowing owls are prey to other raptorial species as well as terrestrial predators, and we frequently observed Swainson's hawks (*Buteo swainsoni*) over the study areas as well as coyotes (*Canis latrans*) and domestic cats and dogs. Vigilance behavior decreased in the transmittered period for owls in 2004, and given the occurrence of potential predators at the study sites, the owls were presumably in greater danger when interacting with their necklaces, although we observed no depredation.

MANAGEMENT IMPLICATIONS

Given the relatively small number of transmittered owls and behavioral variation among all of the owls in our study, further research with larger sample sizes, more locations, and longer duration will be necessary to identify possible long-term negative influences of transmitters. Radiotelemetry provides data that are difficult if not impossible to obtain by other means, but behavioral responses should be taken into account when interpreting results for both the short and long term.

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Appendix. Avian species listed in Tables 3–4 by common and scientific name.

American woodcock (*Scolopax minor*)
Blue grouse (*Dendragapus obscurus*)
Blue-winged teal (*Anas discors*)
Brant (*Branta bernicla*)
Canvasback (*Aythya valisineria*)
Emperor goose (*Chen canagica*)
Gray partridge (*Perdix perdix*)
Hooded warbler (*Wilsonia citrina*)
Mallard (*Anas platyrhynchos*)
Northern bobwhite (*Colinus virginianus*)
Northern goshawk (*Accipiter gentilis*)
Osprey (*Pandion haliaetus*)
Red grouse (*Lagopus lagopus scoticus*)
Redhead (*Aythya americana*)
Ring-necked pheasant (*Phasianus colchicus*)
Rock ptarmigan (*Lagopus mutus*)
Ruffed grouse (*Bonasa umbellus*)
Spotted owl (*Strix occidentalis*)