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Research Article

Effects of Survey Methods on Burrowing Owl Behaviors

JEFFREY A. MANNING,[1] *Fish and Wildlife Resources, College of Natural Resources 107, University of Idaho, Moscow, ID 83844-1136, USA*
ROBB S. A. KALER, *Alaska Maritime National Wildlife Refuge, U.S. Fish and Wildlife Service, 95 Sterling Hwy Suite 1, Homer, AK 99603, USA*

ABSTRACT Monitoring wildlife populations often involves intensive survey efforts to attain reliable estimates of population size. Such efforts can increase disturbance to animals, alter detection, and bias population estimates. Burrowing owls (*Athene cunicularia*) are declining across western North America, and information on the relative effects of potential survey methods on owl behaviors is needed. We designed a field experiment to compare burrowing owl flight distances, times displaced, and probabilities of being displaced between 4 potential population survey methods (single walking surveyor, single vehicle stop, single vehicle stop with 2 surveyors, and double vehicle stop with 2 surveyors), and an experimental control in the agricultural matrix of Imperial Valley, California. Between 25 April and 1 May 2008, we randomly applied survey methods to 395 adult male owls during daylight hours (0700 hours through 1900 hours). All survey methods increased odds of displacing owls from perches. Survey methods with observers outside the vehicle were 3 times more likely to displace an owl than a single vehicle stop where observers remained inside the vehicle. Owls were displaced farther distances by all survey methods compared to control trials, but distances and time displaced did not differ among survey methods. We recommend that surveys for counting owls during the breeding season in agroecystems like the Imperial Valley where high densities of owls nest primarily along the borders of fields be conducted using single vehicle stops with or without 2 surveyors, depending on conditions for locating owls from roads. © 2011 The Wildlife Society.

KEY WORDS agroecosystem, *Athene cunicularia*, behavioral responses, burrowing owl, California, field experiment, Imperial Valley, short-term displacement, survey methods.

Monitoring wildlife populations of management or conservation concern often involves intensive survey efforts to attain reliable estimates of abundance. An increase in survey effort with a carefully selected experimental design can improve precision of estimates and increase statistical power to detect population change (Caughley 1977, Montgomery 1997). However, increased survey efforts may increase disturbance, leading to changes in frequency, distance, and duration of animal displacement during a survey. These short-term behavioral responses may introduce unknown levels of bias into population estimates by altering detection rates and increasing the risk of double counting individuals.

Human disturbance during the breeding season can also decrease productivity and survivorship by disrupting normal behavior and physiology of nesting birds (Knight and Cole 1991). Increased parental activity caused by human presence attracts predators and increases nest predation rates (Martin et al. 2000). Because predation risk increases as a predator approaches, breeding birds exhibit stronger responses to humans at closer distances (Beale and Monaghan 2004). Thus, empirical information on how a species responds to specific survey methods is critical for development of protocols that minimize disturbance to breeding birds during population surveys.

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[1]*E-mail: jeffmanning@vandals.uidaho.edu*

A species of management and conservation concern that would benefit from such information is the burrowing owl (*Athene cunicularia*), a conspicuous inhabitant of grasslands, deserts, agricultural systems, and other arid areas throughout western North America, Florida, and Central and South America (Haug et al. 1993). The burrowing owl is listed as a Species of National Conservation Concern in every United States Fish and Wildlife Service Region where it occurs (U.S. Fish and Wildlife Service 2002). Despite recommendations for standardized range-wide survey protocols (Holroyd et al. 2001, Conway and Simon 2003), various approaches to monitoring burrowing owl populations have been used in local or regional studies, including driving surveys, road-side point-counts, and walking line transects (Conway and Simon 2003).

Methods used to monitor owl populations vary in their potential to cause disturbance. Driving surveys (driving slowly along secondary roads and counting owls and nest sites observed; Arrowood et al. 2001, VerCauteren et al. 2001) allow observers to cover a large geographic area in a short time, but acquisition of accurate locations requires stopping the vehicle at each owl sighting. Road-side point-count surveys (short-duration road-side point-count surveys established along secondary roads; Coulombe 1971, Haug and Didiuk 1993) require that the vehicle is stopped and observers are visible outside the vehicle for brief periods. Walking line-transect surveys or systematic walking surveys (Rodríquez-Estrella and Ortega-Rubio 1993, Martell et al. 1997) are more labor-intensive and involve observers being visible to owls for longer periods. This variability in duration of human disturbance among survey methods may lead to differences in the intensity of behavioral responses by owls (Burger and Gochfeld 1991).

Measuring effects of human disturbance on birds is common (Gill 2007), but behavioral responses of burrowing owls to researchers are poorly understood (Holroyd et al. 2001). Other diurnal raptors respond to human disturbance in a variety of ways, including altered patterns in habitat use (Knight et al. 1991), activity budgets (Steidl and Anthony 2000), nest-site selection (van der Zande and Verstrael 1985), and reproductive success (White and Thurow 1985). The only published study we found on behavioral responses of burrowing owls to human activity reported that owl movements and alertness were positively correlated with vehicular traffic (Plumpton and Lutz 1993). Such findings raise concerns because the vast extent of agricultural and grassland areas where burrowing owls breed often requires vehicles to attain adequate coverage during a population survey (Conway and Simon 2003). Additionally, if owls flush far from their nests during surveys, observers may inadvertently double count individuals resulting in biased detection probabilities and population estimates.

As burrowing owls increasingly occupy agricultural environments across their range in North America (Leptich 1994, Conway et al. 2006, Moulton et al. 2006), these areas will become increasingly important for conservation and management of this species. However, it is in these areas where owls nest in high densities (Haug et al. 1993, Klute et al. 2003, DeSante et al. 2004) that the risk of biased population estimates may be greatest due to double counting. We designed a field experiment to compare short-term behavioral responses of adult male burrowing owls during the breeding season to 4 potential population survey methods (single walking surveyor, single vehicle stop, single vehicle stop with 2 surveyors, and double vehicle stop with 2 surveyors) and an experimental control. Our goal was to compare flight distances, time displaced, and probabilities of being displaced between potential survey methods and provide estimates of differential responses that can be used by researchers when designing survey methods to reduce disturbance and biases.

STUDY AREA

Our study area was located in the Imperial Valley, California, USA, where 1 of the largest concentrations of breeding burrowing owls existed in North America (DeSante et al. 2004). In the early 20th century, this 1,081,320-ha desert ecosystem experienced extensive land conversion to agricultural crops with irrigation water supplied by the Colorado River (Bailey 1994). During our study, fields were intensively managed year-round, with alfalfa, Sudan grass, Bermuda grass, and wheat as the dominant crops.

Burrowing owls in this agroecosystem nested almost entirely within or along irrigation drains, canals, and ditches alongside unpaved maintenance roads that bordered agricultural fields (Coulombe 1971, Rosenberg and Haley 2004). Human activities along these nesting areas included occasional pedestrians and vehicles associated with irrigation maintenance, farming, and road and irrigation repairs.

METHODS

We chose the incubation period (primarily Apr in our study area; Coulombe 1971) to reduce risk of double counting pairs because females incubate underground, whereas males remain sentinel outside near the nest entrance (Martin 1973, Plumpton and Lutz 1993). Similar to data collected during breeding population surveys, we assumed that owls we observed were adult males and responses we measured represented those of adult males regardless of breeding status. We based treatments on walking line-transect, driving, or road-side point-count survey methods recommended or used for owl surveys (Ratcliff 1986, Nicholson and Skiftun 2002, Conway and Simon 2003, Rosenberg and Haley 2004). Treatments differed by the frequency of vehicle stops, visibility of surveyors (i.e., walking or inside or outside a vehicle), and the number of visible observers (1 or 2).

Between 25 April and 1 May 2008, we drove 11 km/hr along randomly chosen maintenance roads across the study area and arbitrarily selected 395 non-neighboring owls $\geq$0.8 km apart. We randomly applied 1 of 4 experimental methods of surveying or a control to each owl for 2 min during daylight hours (0700 hours through 1900 hours), following a balanced design ($n = 79$ owls for each treatment group and control) throughout the day. The 4 treatments were: 1) single walking surveyor, 2) single vehicle stop, 3) single vehicle stop with 2 surveyors, and 4) double vehicle stop with 2 surveyors. Prior to applying a treatment to a focal owl, we positioned a vehicle with 1 observer at a vantage point approximately 50 m from the owl for 5 min because owls that are habituated to vehicles, such as in our study area, tend to be non-responsive to vehicles parked at that distance (Coulombe 1971, Conway and Simon 2003). The observer remained inside the vehicle, and if a focal owl exhibited signs of being disturbed by the presence of the vehicle (head bobbing, multiple flights, or chatter calls; Thomsen 1971) or if the observer lost sight of and could not relocate the owl during this 5-min period, we did not apply the treatment and instead randomly chose another owl.

The experimental control involved only the observer in the parked vehicle. The single walking surveyor treatment represented a walking-based survey along a 200 m line-transect centered on the focal owl and involved 1 person on foot surveying with binoculars along the unpaved road on one side of an irrigation ditch with a 1-min pause at the focal owl. A single vehicle stop survey entailed a vehicle that stopped about 15 m past the shortest distance from the focal owl for 2 min with the engine running, while 2 surveyors remained inside the vehicle. The single vehicle stop represented 1 vehicle-based road-side survey conducted from one side of an irrigation ditch. The single vehicle stop with 2 surveyors represented a vehicle-based road-side or point-count survey (Conway and Simon 2003) similar to the single vehicle stop for 2 min with the engine running, with the addition of 2 surveyors that exited the vehicle and remained visible $<$3 m from it. The double vehicle stop with

2 surveyors represented a vehicle-based road-side or point-count survey method from both sides of an irrigation ditch. In this case, the vehicle stopped for 1 min with the engine running at the same owl twice (representing a survey from both sides of the ditch, where the duration of disturbance was the same but the number of approaches and vehicle stops doubled) and the surveyors exited the vehicle. Vehicles involved in vehicle-based survey treatments traveled 11 km/hr and did not stop except to apply a treatment.

Immediately before we applied a treatment, the observer noted the location of an owl's initial perch, presumed to be its day-time sentry perch (Martin 1973, Plumpton and Lutz 1993). In addition to above-ground locations, we considered owls standing at burrow entrances or in burrows as being at perches. During a treatment, the observer tracked the owl's movements. The flat agricultural landscape enabled us to maintain sight of and continuously track owls up to 250 m away.

After a treatment, the observer continuously tracked the owl for 20 min and recorded the farthest location the owl perched from its initial perch. Although owls perched close to a dirt road sometimes flushed when a vehicle passed, we assumed, as others have (Conway and Simon 2003), that this time period was adequate for owls to resume normal behavior and activity. If an owl returned to <10 m from its initial perch ≤ 20 min after the treatment, the observer recorded the time lapsed and the location of the farthest perch and ended the observation. When an owl did not return to <10 m from its initial perch in ≤ 20 min, the observer recorded the location of the farthest perch and the maximum time the owl was displaced (20 min). We continuously tracked an owl for the full 20 min, even if the applied treatment caused the owl to retreat into a burrow. For these samples ($n = 15$), we did not record distance, but we used the time an owl was out-of-sight as the time away from its perch. If an owl did not leave its initial perch by the end of the observation period, we recorded the maximum distance and time displaced as 0. With the exception of color, all vehicles were identical in make and model, and were required to keep lights off and windows closed during treatments. We recorded the color (white, silver, blue or gray, green, black) of the vehicle that applied the treatment. After the 20-min observation period, the observer used a Trimble GeoXM Global Positioning System (GPS) receiver, laser range finder, and magnetic compass with sighting mirror to record the location of an owl's initial perch. If during the 20-min treatment period a disturbance event occurred (e.g., vehicle traffic, pedestrians on the right-of-way) we abandoned the observation and randomly selected another owl for the treatment.

We used GPS locations, compass bearings, and range finder distances with ArcGIS 9.2 to measure the maximum distances owls were displaced and used a logistic model with a binomial response (displaced, no response) to assess whether the probability that an owl was displaced differed among survey methods (Hosmer and Lemeshow 1989). We used the area under a receiver operating characteristic (ROC) curve to assess how well the model parameters predicted when an owl would be displaced (Hanley and McNeil 1982, Heagerty et al. 2000). We used odds ratios to compare how much more likely it was for an owl to be displaced by a survey method over the control (Hosmer and Lemeshow 1989).

We used 1-way analysis of variance (ANOVA) tests to assess if the duration of time or distance that a displaced owl traveled differed among treatments and our control. We used only data from owls that were displaced, $\log_e(x)$-transformed distance displaced, and adjusted the sums of squares for unbalanced data (Montgomery 1997:79). When the ANOVA indicated a difference among treatments, we used Tukey–Kramer honestly significant difference (HSD) multiple comparison tests to determine which treatments differed from each other or the control.

We also conducted post hoc analyses to assess if time of day or car color had a differential effect on the distance or time owls were displaced. To evaluate effects of time of day on distance moved, we used only data from displaced owls and pooled data across survey treatments because we applied treatments equally throughout the day. As breeding males remain close to nests during mid-day and foraging activities are highest during crepuscular periods (Thomsen 1971, Martin 1973, Moulton et al. 2004), we fit a linear regression model that predicted distance as a second-degree quadratic function of time of day. For car color, we used data from the single vehicle stop surveys to avoid any confounding responses to surveyors on foot. In both analyses, we $\log_e(x)$-transformed response variables. We based all statistical analyses on a significance level of 0.05 and conducted analyses using Program JMP 7.0.1 (SAS Institute, Inc., Cary, NC).

RESULTS

Probability of an owl being displaced during a survey differed among survey methods (whole model test: $\chi^2_4 = 82.2$, $P < 0.001$; Fig. 1), with the logistic model predicting fairly well when an owl would be displaced (area under the ROC curve = 0.74). Odds ratios showed that all survey methods increased the probability of being displaced by ≥ 5 times compared to the control. The single vehicle stop was least likely to displace an owl (odds ratio = 4.9, SE = 1.59), followed by single walking surveyor

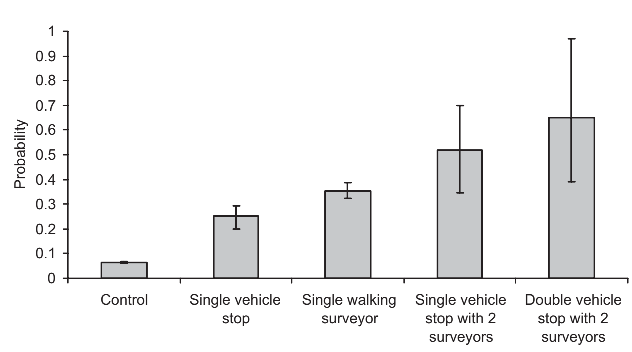

Figure 1. Predicted displacement of male burrowing owls by a survey method compared to an experimental control during the incubation period of the breeding cycle in Imperial Valley, California, USA, 25 April–1 May 2008.

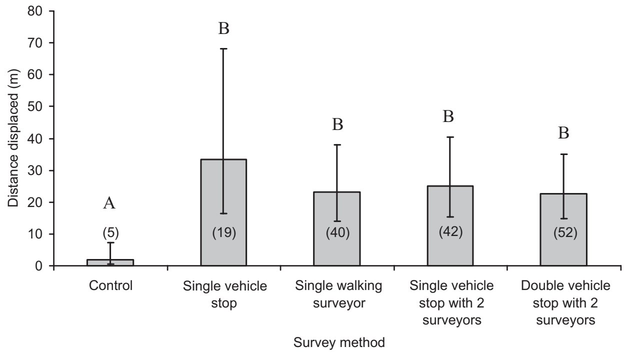

Figure 2. Average distance that male burrowing owls moved when displaced by a survey method during the incubation period of the breeding cycle in Imperial Valley, California, USA, 25 April–1 May 2008. Capital letters pertain to significant groupings based on Tukey–Kramer honestly significant difference test. Parentheses include sample size. Vertical lines are 95% confidence intervals. Data are untransformed.

(15.1, SE = 1.69), single vehicle stop with 2 surveyors (15.5, SE = 1.67), and double vehicle stop with 2 surveyors (26.7, SE = 1.67).

Survey methods displaced owls ≤18 times farther than the control group ($F_{4,157} = 3.51$, $P = 0.009$; Tukey–Kramer HSD, $P < 0.05$; Fig. 2), The farthest distance we observed an owl displaced was 211 m during a single vehicle stop, but distances did not differ among survey methods (Tukey–Kramer HSD, $P > 0.05$). Duration of time that displaced owls were away from initial perches did not differ ($F_{4,157} = 0.96$, $P = 0.43$). Because of the similar distances that survey methods displaced owls and most (94%) owls in the control group did not move, we pooled data from the 4 survey methods to test for effects of time of day. Time of day did not affect the distance displaced owls moved during surveys (adjusted $r^2 = 0.005$, $F_{2,157} = 1.39$, $P = 0.25$), and we did not detect a strong effect of car color on the distance or time an owl was displaced ($F_{4,78} = 2.41$, $P = 0.06$, $F_{4,78} = 2.26$, $P = 0.07$, respectively). Black and silver vehicles displaced owls the longest and silver vehicles displaced owls the farthest (Table 1).

DISCUSSION

Our field experiment demonstrated that adult male burrowing owls differed in their responses to survey methods during the incubation stage of the breeding cycle. An increase in the frequency of vehicle stops and presence of surveyors outside of vehicles increased the probability of displacing owls from perches. Once displaced during a survey, owls moved farther distances than in control treatments without surveys. Similar patterns involving movements and alertness of burrowing owls in response to vehicular traffic have been reported (Plumpton and Lutz 1993); the increased frequency of movements in response to researchers may affect nesting behaviors and increase predation risk. Because neighboring nest burrows in the Imperial Valley can be ≥7 m (Rosenberg and Haley 2004), increased movements ≤33 m may also increase the risk of double counting.

Many factors beyond those we measured may affect the flight distance of owls following a disturbance. As with other species, additional factors may include group size (Burger and Gochfeld 1991), habituation to disturbance (Burger and Gochfeld 1991, Stalmaster and Kaiser 1997), angle from which surveyors approach (Burger and Gochfeld 1981, Fernández-Juricic et al. 2005), color of surveyors' clothing (Gutzwiller and Marcum 1997), and habitat availability (Gill et al. 2001). Although we did not investigate or control for these potential factors, the trend in owl responses demonstrates that all survey methods increased displacement distances, and vehicle color weakly affected displacement distances and duration, with owls responding the least to white and blue-gray colors. Additionally, we consistently maintained the 50 m distance between a focal owl and the observer's vehicle across treatments, and it should not have affected flushing distance (Conway and Simon 2003). However, longer approach distances may be necessary in areas where owls are less habituated (Conway and Simon 2003).

Owls experience different levels of human disturbance across their range, and habituation of male owls likely varies depending on background levels of vehicles and pedestrians. The primary sources of potential disturbance in the Imperial Valley were vehicles, machinery, and pedestrians related to agricultural activities. Owls exposed to these repeated disturbances may respond less and at closer distances to passing vehicles and might require less time to resume undisturbed behaviors after a vehicle stops or a surveyor approaches (Burger and Gochfeld 1991, Rees et al. 2005). Our results suggest that habituation to vehicles and pedestrians in agricultural areas like the Imperial Valley may lead to indiscernible differences in how long or far owls are displaced throughout the day by survey methods. Future studies should examine the effects of these and other potential survey methods on owl behavior and demography across a range of background levels of vehicles and pedestrians throughout the breeding cycle.

Table 1. Duration of time and distance that we observed male burrowing owls to be displaced according to color of survey vehicles used during single vehicle stops in Imperial Valley, California, USA, 25 April–1 May 2008. Data are untransformed.

		Time displaced (min)		Distance displaced (m)	
Vehicle color	***n***	$\bar{x}$	**SD**	$\bar{x}$	**SD**
Black	10	4.10	8.39	4.97	10.50
Blue-gray	12	0.17	0.58	2.59	8.98
Cream, gray, green	18	0.28	0.67	7.34	19.37
Silver	20	3.90	6.62	11.38	28.04
White	19	1.58	4.66	3.24	7.65

MANAGEMENT IMPLICATIONS

Probability of displacing owls during surveys depends on the type of survey method used, and this difference should be considered when selecting a method for a particular region. We recommend that population surveys conducted during the breeding season in the Imperial Valley be conducted with a method involving a single survey pass. Depending on the interest of managers, our odds ratios can be used to assess tradeoffs between disturbing owls and the types and quality of data acquisition among the single survey pass methods. The single vehicle stop can be used to cover large areas and minimize disturbance, but it prevents observers from exiting the vehicle to acquire additional data (e.g., burrow location and occupancy status). And, in areas where vegetation obscures burrows or owls from roads, detection probabilities obtained from road-side surveys are expected to decline with increased distance from the road, potentially leading to population underestimates and inaccurate data on spatial distributions when counts are not corrected for such detection bias. Walking line-transect surveys analogous to our single walking surveyor treatment in these low visibility conditions off of roads allows more thorough detection of owl nests and owls; however, this increased information must be weighed against the increased likelihood of owls moving when surveyed on foot versus those observed by car, which increases owls' predation risk. Alternatively, such data can be collected using the single vehicle stop with 2 surveyors without increasing the probability of displacing owls beyond that associated with walking. For both methods, we recommend using white or blue-gray vehicles.

The 4 methods we tested displaced owls farther than without surveys, suggesting that human disturbance caused by surveys exceeds the tolerance of habituated owls. Because disturbance can decrease survivorship and affect nesting behaviors, and owls in other areas are likely to be less habituated, we recommend that researchers across the owl's range minimize disturbance around nesting areas. Our odds ratios may be used to help inform managers in establishing a minimum displacement probability threshold that could be used in selecting a survey method in agricultural areas by combing these ratios with demographic information (e.g., productivity, predation risk) related to the frequency of owl flights.

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