Management and Conservation Article

Factors Affecting Detection of Burrowing Owl Nests During Standardized Surveys

COURTNEY J. CONWAY,[1] *United States Geological Survey, Arizona Cooperative Fish and Wildlife Research Unit, School of Natural Resources, 325 Biological Sciences East, University of Arizona, Tucson, AZ 85721, USA*

VICTORIA GARCIA, *Arizona Cooperative Fish and Wildlife Research Unit, School of Natural Resources, 325 Biological Sciences East, University of Arizona, Tucson, AZ 85721, USA*

MATTHEW D. SMITH,[2] *Arizona Cooperative Fish and Wildlife Research Unit, School of Natural Resources, 325 Biological Sciences East, University of Arizona, Tucson, AZ 85721, USA*

KATIE HUGHES, *Arizona Cooperative Fish and Wildlife Research Unit, School of Natural Resources, 325 Biological Sciences East, University of Arizona, Tucson, AZ 85721, USA*

ABSTRACT Identifying causes of declines and evaluating effects of management practices on persistence of local populations of burrowing owls (*Athene cunicularia*) requires accurate estimates of abundance and population trends. Moreover, regulatory agencies in the United States and Canada typically require surveys to detect nest burrows prior to approving developments or other activities in areas that are potentially suitable for nesting burrowing owls. In general, guidelines on timing of surveys have been lacking and surveys have been conducted at different times of day and in different stages of the nesting cycle. We used logistic regression to evaluate 7 factors that could potentially affect probability of a surveyor detecting a burrowing owl nest. We conducted 1,444 detection trials at 323 burrowing owl nests within 3 study areas in Washington and Wyoming, USA, between February and August 2000–2002. Detection probability was highest during the nestling period and increased with ambient temperature. The other 5 factors that we examined (i.e., study area, time of day, timing within the breeding season, wind speed, % cloud cover) interacted with another factor to influence detection probability. Use of call-broadcast surveys increased detection probability, even during daylight hours when we detected >95% of owls visually. Optimal timing of surveys will vary due to differences in breeding phenology and differences in nesting behavior across populations. Nevertheless, we recommend ≥3 surveys per year: one that coincides with the laying and incubation period, another that coincides with the early nestling period, and a third that coincides with the late nestling period. In northern latitudes, surveys can be conducted throughout the day. (JOURNAL OF WILDLIFE MANAGEMENT 72(3):688–696; 2008)

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Surveys document distribution and estimate abundance of animals most effectively when they are conducted in ways that provide estimates of (or account for variance in) detection probability (Eberhardt et al. 1999, White 2005). Whether or not investigators estimate detection probability during surveys, designing survey protocols to reduce variance in detection probability is essential. Detection probability during standardized surveys often varies among observers but can also vary spatially (i.e., across regions due to variation in weather, predation risk, and other extrinsic factors) and temporally (based on time of day, stage of the reproductive cycle, and timing within the breeding season; Pollock et al. 2002, Diefenbach et al. 2003, Kery and Schmid 2004). Identifying factors that cause variation in detection probability during standardized surveys is vital for studies that compare population densities or abundance across space or time (White 2005). An accounting of sources of variation in detection probability during analysis of survey data enables those designing future surveys to provide guidance on timing surveys to help reduce effects of nuisance variables.

Identifying factors that influence detection probability during standardized surveys is especially important for species of conservation concern. A good example is burrowing owls (*Athene cunicularia*). Populations of burrowing owls have declined in many portions of their range (Sheffield 1997, Desmond et al. 2000, Conway and Pardieck 2006). Burrowing owls are listed as Endangered in Canada, and a Species of National Conservation Concern in the United States (Wellicome and Haug 1995, U.S. Fish and Wildlife Service 2002). Burrowing owls are also listed, or being considered for listing, as Threatened or Endangered in many western states and all 4 western provinces (James and Espie 1997). As a result, a range-wide survey effort has been recommended to complement the North American Breeding Bird Survey (Holroyd et al. 2001, Conway and Simon 2003). Such a survey would provide more rigorous estimates of trends in burrowing owl populations at local, regional, and continental scales. Moreover, effective management and conservation of burrowing owls requires development and implementation of specialized monitoring methods (Andelman and Stock 1994) because of low nesting densities and patchy distribution throughout the species' range (Martell et al. 1997, Todd 2001, Conway and Simon 2003).

Numerous regulatory agencies and nongovernmental organizations have developed guidelines for how to conduct burrowing owl surveys prior to development in an area (California Burrowing Owl Consortium 1997, Arizona Game and Fish Department 2007, New Mexico Department of Game and Fish 2007). Such guidelines need to

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[1] *E-mail: cconway@usgs.gov*

[2] *Present address: Department of Zoology, University of Florida, 316 Bartram Hall, Gainesville, FL 32601, USA*

include explicit information on timing of surveys and number of repeat visits needed to ensure that all nests are detected. However, time of day and timing within the breeding season has varied widely among past surveys of regional burrowing owl populations. Some surveys have been conducted only during the early breeding season (Feb–May; Arrowood et al. 2001), whereas others have been conducted during the later part of the breeding season (May–Jul; Rich 1984, 1986; Haug and Didiuk 1993; Schmutz 1996, Martell et al. 1997; Korfanta et al. 1999; Orth and Kennedy 2001; Shyry et al. 2001; Conway and Simon 2003; DeSante et al. 2004). Surveys have also differed widely in the time of day that they have been conducted, with some conducted from sunrise through mid-morning (Martell et al. 2001, Murphy et al. 2001, Conway and Simon 2003), some conducted in the evening (Ross 1974), some conducted both in the morning and evening (Haug and Didiuk 1993, Martell et al. 1993, California Burrowing Owl Consortium 1997, Bartels and Tabor 1999, Estabrook 1999, Korfanta et al. 1999, VerCauteren et al. 2001, DeSante et al. 2004, Rosenberg and Haley 2004), and still others conducted throughout the day (Shyry et al. 2001, Sidle et al. 2001, Conway and Simon 2003). Even the timing of morning surveys has varied among studies (e.g., 0500–1000 hr, 0600–1000 hr, 0600–1100 hr, sunrise–4 hr after sunrise). Allowing surveys during a broad range of possible survey times has logistical benefits and time of day may not affect detection probability of burrowing owls as much as it does other bird species whose detections are mostly auditory. Indeed, virtually all detections of burrowing owls during roadside point-count surveys in Wyoming were visual (rather than auditory) detections (Conway and Simon 2003).

Weather conditions, such as wind speed and amount of precipitation, warranting cancellation of surveys have also varied among surveys (Haug and Didiuk 1993, Schmutz 1996, California Burrowing Owl Consortium 1997, Martell et al. 1997, Bartels and Tabor 1999, Korfanta et al. 1999). Eliminating, or at least reducing, this variation among surveys would allow more rigorous estimates of population density, percent occupancy of nest sites, and comparisons of relative abundance across regions or among areas with different land uses. However, recommending range-wide protocols for conducting standardized burrowing owl surveys requires better information on factors influencing detection probability of breeding burrowing owls. Range-wide protocols will also provide guidelines for regulatory agencies regarding required timing and conditions for surveys to ensure compliance with the Migratory Bird Treaty Act. We sought to determine optimal survey timing and to identify extrinsic factors that cause variation in detection probability of burrowing owls by conducting detection trials at 323 nests within 3 separate study areas in the western United States.

STUDY AREA

We conducted detection trials in 3 study areas (2 in eastern WA and one in northeastern WY, USA) at which we had ongoing demographic studies of burrowing owls (Conway et al. 2006, Lantz et al. 2007, Smith and Conway 2007). All burrowing owl nests in Wyoming were within black-tailed prairie dog (*Cynomys ludovicianus*) colonies, whereas nests at the 2 study areas in Washington were primarily in burrows created by American badgers (*Taxidea taxus*), California ground squirrels (*Spermophilus beecheyi*), yellow-bellied marmots (*Marmota flaviventris*), or erosion (i.e., under concrete irrigation troughs).

The study area in central Washington was approximately 3,600 km^2 and located in Adams and Grant counties. The study area encompassed the towns of Moses Lake, Warden, and Othello. The primary land use was irrigated cropland but also included pasture, urban, suburban, and undisturbed shrub-steppe. Most nest burrows were adjacent to agricultural fields. Elevation varied from 316 m to 398 m above sea level, and annual precipitation in the area was usually <25 cm, which fell primarily as rain from October to May (Blackwood et al. 1997).

The study area in southeastern Washington was approximately 1,500 km^2 and located in Benton, Franklin, and Walla Walla counties. Nest burrows were concentrated in and around the towns of Pasco, Kennewick, Richland, and West Richland. The primary land uses included urban, suburban, industrial, abandoned fields, and undisturbed shrub-steppe. Elevation varied from 109 m to 150 m above sea level, and annual precipitation averaged 18 cm, which fell primarily as rain from November to February (Hoitink and Burk 1995, Benton Clean Air Authority 2004).

The study area in northeastern Wyoming was approximately 2,300 km^2 and located in the Thunder Basin National Grassland (TBNG) within Campbell, Weston, and Converse counties. The study area was near the towns of Wright, Newcastle, and Douglas. Primary land uses included cattle and sheep grazing and mineral extraction. Topography within TBNG included valleys, rough breaks and badlands, steep coniferous mesas, and low riparian bottomlands, with elevation ranging from 1,090 m to 1,580 m. Annual precipitation varied from 15 cm to 40 cm (Western Regional Climate Center 2007).

METHODS

At each study area, we conducted detection trials during a variety of time periods throughout the day (0400–2400 hr) between 15 February and 15 August 2000–2002. Detection trials consisted of a 3-minute passive segment followed by a 3-minute call-broadcast segment (6 min total). We broadcast burrowing owl calls because numerous studies have reported that call-broadcast surveys increased detection probability of burrowing owls relative to passive surveys (Haug and Didiuk 1993, Conway and Simon 2003). We broadcast burrowing owl calls at 80 decibels (measured 1 m from the speaker) using a portable cassette player (Optimus Model SCP-88; Radio Shack, Fort Worth, TX) and an amplified speaker (Radio Shack Cat. No. 32-2040). The 3-minute call-broadcast segment consisted of 30 seconds of calls followed by 30 seconds of silence, with this pattern repeated 3 times. The first 2 30-second call periods consisted of the primary song of male burrowing owls (*coo-coo*; Haug et al. 1993) and the final 30-second call period consisted of an alarm call (*quick-quick-quick*).

We examined the extent to which the following 7 factors influenced detection probability of burrowing owls: study area, stage of the nesting cycle, time of day, timing within the breeding season, wind speed, percent cloud cover, and ambient temperature. We included the 3 weather variables because past authors have assumed that high ambient temperature (>30° C) and high winds (>20 km/hr) reduce detection probability (Shyry et al. 2001). We did not expect detection probability to be related to time of day or timing within the breeding season in a linear fashion, so we used discrete variables by classifying each trial into 1 of 10 periods of the day (hr; 0400–0559, 0600–0759, 0800–0959, 1000–1159, 1200–1359, 1400–1559, 1600–1759, 1800–1959, 2000–2159, and 2200–2359) and 1 of 3 time periods within the breeding season (early spring, 15 Feb–31 Mar; late spring, 1 Apr–10 May; and summer, 11 May–15 Aug) prior to analysis. We restricted our analysis to detection trials at nest burrows where juveniles had not yet reached fledging age (44 days; Landry 1979).

In addition to periodic detection trials, we used a standardized protocol to monitor all burrows once per week from February through September. We first observed burrows from >100 m away using binoculars to check for owl activity and then we slowly approached each burrow on foot to look for signs of use (e.g., an owl that retreats or flushes from burrow, regurgitated pellets, feathers, nest lining, whitewash, or footprints) or vacancy (e.g., presence of cobwebs at burrow entrance or no new regurgitated pellets). This initial period of observation typically lasted approximately 10 minutes. Ten minutes of observation is sufficient because the maximum number of juvenile owls observed during an individual nest visit is typically seen during the first 10 minutes of that visit (Gorman et al. 2003). During weekly nest visits, we also recorded presumed stage of the nesting cycle and number of adult and juvenile owls we observed. We also used an infrared video probe (Peeper Video Probe; Sandpiper Technologies, Manteca, CA) to examine nest contents of many of the occupied burrows. Repeated use of the peeper did not affect nest abandonment or nesting success (V. Garcia and C. Conway, University of Arizona, unpublished data). Use of the peeper helped us determine stage of the nesting cycle and number of eggs or juveniles present when we observed no owls at the burrow entrance. We used a standardized protocol to estimate the following dates for each nest: male arrival, female arrival, first egg laid, last egg laid, first egg hatched, last egg hatched, first nestling fledged, and last nestling fledged (Garcia et al. 2007). From this information, we classified each detection trial into 1 of 6 stages: unpaired owl (occupied burrows defended by an ad M prior to time we first detected a F), prelaying (burrows occupied by a pair of owls but no eggs or juv present), laying, incubation, early nestling (from the day the first egg hatches until the first nestling reaches 20 days of age), and late nestling (from the day the first nestling reaches 21 days of age until the first nestling reaches 44 days of age; Garcia and Conway, in press).

At the end of each detection trial, we recorded ambient temperature, wind speed (based on the Beaufort Number scale from 0 to 5; Sauer et al. 2005), and percent of the sky obstructed by clouds. Ambient temperature varied greatly among detection trials from −5° C to 41° C and cloud cover varied between 0% and 100%. We attempted to conduct the same number of trials at each nest within each study area. However, the number of trials conducted at each nest varied ($\bar{x} = 4.5 \pm 0.2$, range = 1–18) due to variation in the date that we located nests, whether a nest failed, and differences among study areas in person-time available for conducting trials each year. We did not conduct >2 detection trials per week at any nest.

We used 26 different observers to conduct detection trials. Variation among observers in detection probability at previously undetected nests was the topic of a previous paper (Conway and Simon 2003). We assumed observer bias was negligible in our study because observers always knew locations of focal nests prior to conducting detection trials. Hence, observers did not scan the entire 360° around them as they might during a routine point-count survey, but rather observers focused their attention in the direction of focal nest burrow(s). Focusing attention in the direction of the focal burrow was appropriate because we were interested in the extent to which different extrinsic factors (stage of the nesting cycle, time of day, and weather) influenced probability that an observer would detect a burrowing owl nest. In some locations, >1 occupied nest burrow was within 400 m of the observer during a detection trial. In those situations (327 of 1,444 detection trials), the observer focused attention on, and recorded data for, all nests simultaneously.

For nests that were >100 m from a road, observers conducted trials 100 m from nests in a random direction. For nests that were <100 m from a road, observers conducted trials from the shoulder of the road approximately 100 m from nests. We increased this distance to 150 m from nests (or even further at certain nests) at our Wyoming study area because we noticed that owls often flushed from nests before we could get within 100 m. Due to limited property access at all 3 of our study areas, we conducted some trials >100 m from nest burrows. Moreover, distance from the observer to nest burrows varied between 5 m and 350 m even in locations where we had full property access because observers sometimes recorded data for ≥2 nests simultaneously (when additional nests were within 400 m of the observer during a trial). However, observers were 90–175 m from nest burrows during most (83%) detection trials, and distance to nest burrows did not influence whether we detected owls at nests ($t_1 = 0.2$, $P = 0.836$) because the observer knew the location of nests (and focused attention toward that location) during trials. We were careful not to disturb owls prior to starting trials. We

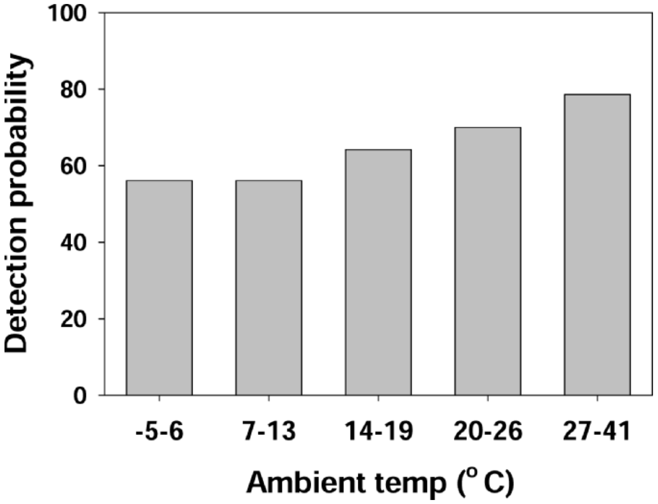

Figure 1. Percentage of burrowing owl nests detected during detection trials increased as ambient temperature increased in northeastern Wyoming and eastern Washington, USA, 2000–2002. Number of detection trials upon which the percentages are based (from left to right): 330, 392, 349, 303, 70. Trials consisted of a 3-minute passive segment followed by a 3-minute call-broadcast segment.

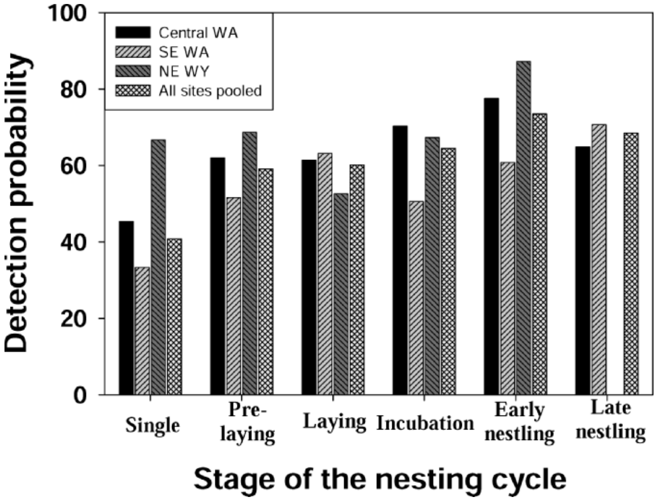

Figure 2. Percentage of burrowing owl nests detected during detection trials differed among stages of the nesting cycle in northeastern Wyoming and eastern Washington, USA, 2000–2002. The early nestling period is from the day the first egg hatches until the first nestling reaches 20 days of age, and the late nestling period is from the day the first nestling reaches 21 days of age until the first nestling reaches 44 days of age. Number of detection trials upon which the percentages are based (from left to right): central Washington (22, 416, 70, 165, 85, 37), southeastern Washington (57, 186, 19, 85, 51, 41), northeastern Wyoming (15, 16, 19, 110, 47, 3), and all 3 areas pooled (94, 618, 108, 360, 183, 81).

terminated trials if a bird appeared to flush from the focal burrow in response to our presence prior to starting trials. For each owl detected, observers recorded all survey segments during which each bird was heard or seen: first, second, or third minute of passive period, first 30-second call period, first 30-second silent period, second 30-second call period, second 30-second silent period, third 30-second call period, and third 30-second silent period. We used this information to examine the effectiveness of call-broadcast surveys relative to solely passive surveys. Observers also recorded whether each owl was detected via visual, auditory, or both types of cues.

We conducted logistic regression analysis with stepwise variable selection with owl(s) detected (yes or no) as the response variable and the following 7 explanatory variables (and all 2-way interactions among those variables): study area (central WA, southeastern WA, or northeastern WY), stage of the nesting cycle (unpaired ad, prelaying, laying, incubation, early nestling, late nestling), time of day, timing within the breeding season (early spring, late spring, summer), wind speed, percent cloud cover, and ambient temperature (° C). We did not include detection trials at nests with unpaired males or pairs (prelaying) unless we later found evidence that eggs were laid at those burrows.

RESULTS

We conducted 1,444 detection trials at 323 burrowing owl nests within 3 study areas in Washington and Wyoming between February and August 2000–2002. Detection probability was 71.0% in northeastern Wyoming, 65.0% in central Washington, and 52.4% in southeastern Washington. We found that ambient temperature and stage of the nesting cycle influenced the probability of detection (Figs. 1, 2), and the model identified 4 important interactions (timing within the breeding season × time of day, % cloud cover × study area, ambient temp × time of day, and ambient temp × wind speed) as having the greatest effect on detection probability (Table 1; Figs. 3–5).

Detection probability increased as ambient temperature increased (Fig. 1) and was highest during the nestling stage (Fig. 2). The relationship between detection probability and time of day changed throughout the course of the breeding season (Fig. 3). In general, detection probability was >60% between 0600 hours and 1000 hours throughout the breeding season, slightly lower (40–70%) between 1200 hours and 1600 hours, >60% again prior to sunset (1600–1800 hr in Feb–Mar, 1800–2000 hr in Apr–Aug), and then declined to 20–50% after sunset. Of owls detected during daylight hours (0600–2000 hr), we detected >90% visually (Fig. 3). Proportion of auditory detections increased substantially after dusk (2000–2400 hr; Fig. 3) and detection probability from 2200 hours to 2400 hours went from 52% early in the breeding season to 24% later in the breeding season (Fig. 3).

Detection probability was low (36%) during periods of high cloud cover in southeastern Washington, but we saw no such relationship at the other 2 study areas (Fig. 4). Detection probability decreased slightly as wind speed increased, but the pattern was most noticeable when ambient temperature was <6° C (Fig. 5).

Number of new owls detected should decline with each successive 1-minute interval during a survey. Call-broadcast surveys increased number of owls detected; we detected more owls during the final 3 minutes (the call-broadcast segment) of our 6-minute surveys than we would have had we conducted 6-minute passive point-count surveys (Fig. 6). However, inclusion of alarm calls in the call-broadcast

Table 1. Factors affecting whether surveyors detected burrowing owls during 1,444 detection trials conducted at 323 nests in northeastern Wyoming and eastern Washington, USA, 2000–2002. We based parameter estimates and statistics on logistic regression analysis with stepwise variable selection. Nest detected (yes or no) was the response variable. Possible explanatory variables included study area (central WA, southeastern WA, and northeastern WY), stage of the nesting cycle (unpaired ad, prelaying, laying, incubation, early nestling, late nestling), time of day, timing within the breeding season (early spring, late spring, summer), wind speed, percent cloud cover, ambient temperature, and all 2-way interactions.

Variable	β	SE(β)	Wald χ^2	df	P	Exp(β)
Ambient temp	−0.025	0.011	5.3	1	0.022	0.975
Stage of the nesting cycle			15.2	5	0.010	
Timing within breeding season × time of day			32.7	18	0.018	
Study area × cloud cover			24.2	2	<0.001	
Ambient temp × time of day			45.1	9	<0.001	
Ambient temp × wind speed	−0.003	0.001	6.3	1	0.012	0.997

sequence (during the sixth min) did not appear to increase detection probability appreciably (Fig. 6). Of the 385 owls we initially detected during the 3-minute call-broadcast segment of our detection trials, we initially detected 69.6% during one of the 3 30-second call-broadcast periods, whereas we initially detected only 30.4% during one of the 3 30-second passive periods that occurred after each call-broadcast period ($\chi^2_1 = 59.2$, $P < 0.001$).

DISCUSSION

Many factors affect detection probability of burrowing owl nests, with the importance of each potentially varying among sites. Moreover, relationships are often not straightforward; the effect of one extrinsic factor on detection probability was often influenced by another extrinsic factor. We found that detection probability increased with increasing ambient temperature, but this relationship was affected by both time of day and wind speed. Detection probability of burrowing owls also was positively correlated with ambient temperature in Texas, USA (Ross 1974). Such differences in detection probability can lead to erroneous estimates of population size or population trends of burrowing owls and they need to be considered when comparisons of population density are made among study sites (DeSante et al. 2004).

We found detection probability to be high and relatively constant throughout the day, especially during the nestling period. Detection probability also did not differ between morning and evening surveys in Saskatchewan and Alberta, Canada, but owls were more vocal during morning and evening surveys in Alberta (Haug and Didiuk 1993). Hence, survey efforts seeking to locate burrowing owl nests (at least in northern latitudes) need not restrict surveys to early morning hours. However, the relationship between time of day and detection probability does vary regionally; detection probability of burrowing owl nests in the southwestern United States is much lower during mid-day when owls retreat into their burrows to avoid high ambient temperatures (C. Conway, personal observation). Detection probability was noticeably less between dusk and dawn (during nighttime hr) at all 3 of our study areas (also see Haug and Didiuk 1993). The relationship between detection probability and time of day differed depending on timing within the breeding season, which was not surprising because days became longer as the season progressed. Because this increase in day length varies from one location to the next and even within the same region, we found that optimal timing for surveys in one location may not be the optimum in another location. Detection probability of individual owls decreased from April to June in Saskatchewan (Haug and Didiuk 1993), but we failed to detect such a decline.

Detection probability was greater in northeastern Wyoming (71%) compared to our 2 study areas in Washington but was similar to previous estimates from Wyoming, in which owls were detected on 79% of detection trials at occupied nests (Conway and Simon 2003). Detection probability was lower in other locations such as South Dakota where 49% of nests were detected (Martell et al. 1997). High detection probability in Wyoming was surprising given that nesting burrowing owls were much less tolerant of human activity in the vicinity of their nests compared to our other 2 study areas (C. Conway, personal observation). The greater detection probability in Wyoming could have been due to several behavioral differences. For example, burrowing owls in Wyoming may have flushed more readily (rather than retreat into their nest burrows) during our surveys, or they may have spent a greater proportion of daylight hours standing at the entrance to their nest burrows compared to owls in Washington. Burrowing owls often stand at the entrance to their nest burrow during daylight hours (Thomsen 1971, Haug and Didiuk 1993, Conway and Simon 2003). Variation in the amount of time owls spend standing at the entrance of nest burrows might be related to variation among sites in 1) availability of suitable nest burrows (owls may spend more time standing in front of their nest burrow in areas where nests are more limited), 2) frequency of extra-pair copulations, 3) mid-day temperatures, 4) availability of food (owls may spend less time foraging and more time at their burrow entrance when food is abundant), or 5) frequency of predation or nest depredation. A better understanding of benefits and drawbacks associated with proportion of daylight hours that an owl spends standing in front of its nest burrow entrance would improve our understanding of why detection probability of burrowing owl nests varies temporally and spatially.

Detection probability was greatest during the nestling

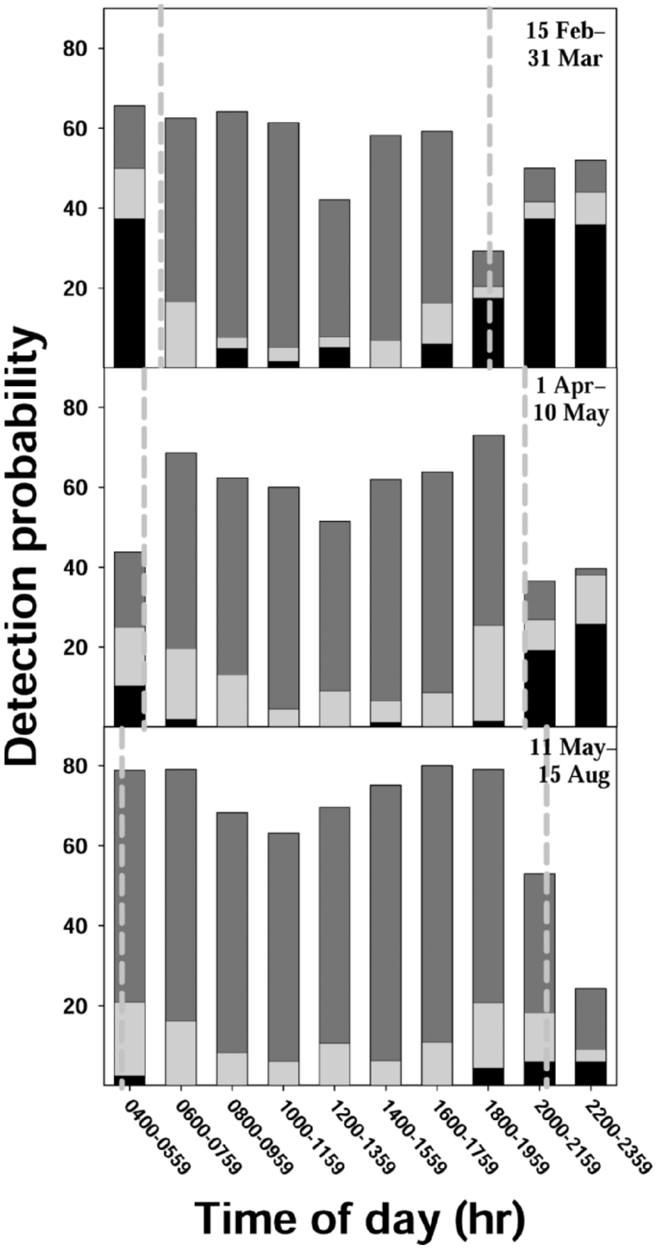

Figure 3. Percentage of burrowing owl nests detected during detection trials differed with time of day and timing within the breeding season in northeastern Wyoming and eastern Washington, USA, 2000–2002. Percentage of trials that we recorded only visual detections (dark gray), only auditory detections (black), and both visual and auditory detections (light gray) differed with time of day and timing within the breeding season. Dashed vertical lines indicate average dawn and dusk. Number of detection trials upon which the percentages are based (from left to right): 15 February–31 March (32, 49, 37, 54, 37, 42, 44, 33, 24, 25), 1 April–10 May (51, 53, 69, 62, 63, 71, 59, 69, 51, 61), and 11 May–15 August (34, 39, 47, 62, 54, 50, 51, 52, 40, 29).

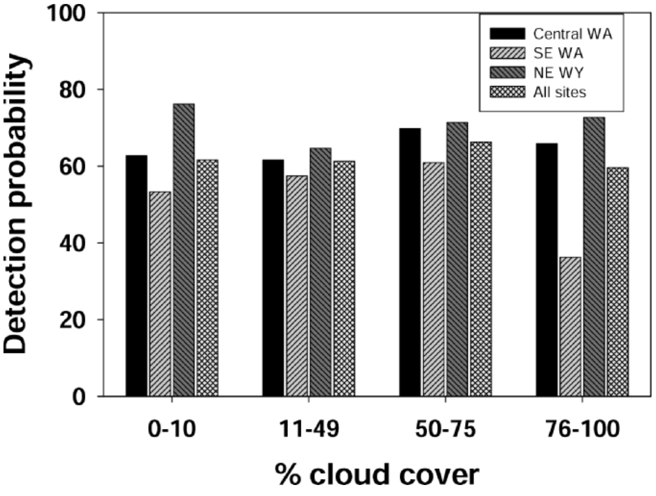

Figure 4. Percentage of burrowing owl nests detected during detection trials decreased when cloud cover exceeded 75% in southeastern Washington, but not in central Washington or northeastern Wyoming, USA, 2000–2002. Number of detection trials upon which the percentages are based (from left to right): central Washington (185, 177, 169, 264), southeastern Washington (137, 73, 134, 95), northeastern Wyoming (63, 68, 35, 44), and all 3 areas pooled (385, 318, 338, 403).

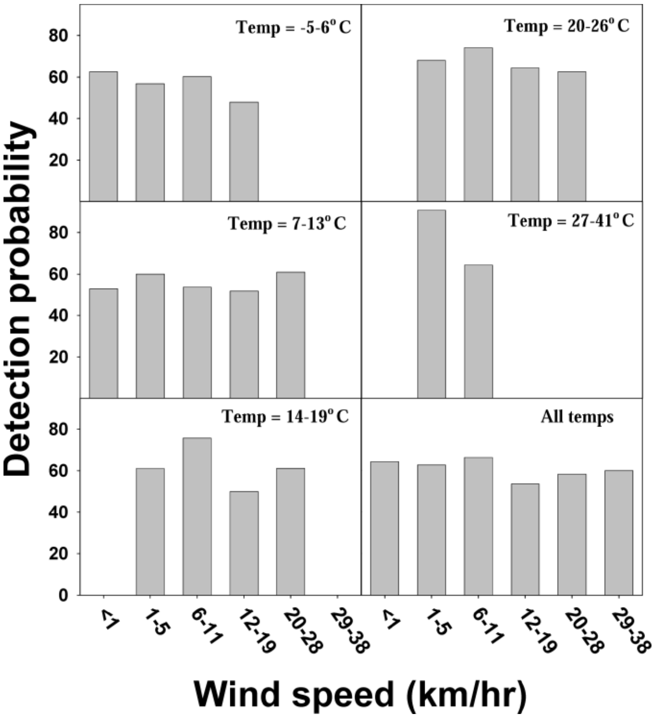

Figure 5. Effect of wind speed on detection probability of burrowing owl nests during detection trials was affected by ambient temperature in northeastern Wyoming and eastern Washington, USA, 2000–2002. We based wind speed categories on the 0 to 5 Beaufort Number scale (Sauer et al. 2005). Number of detection trials upon which the percentages are based (from left to right): −5–6° C (24, 148, 98, 50, 9, 1), 7–13° C (17, 140, 123, 83, 23, 6), 14–19° C (9, 100, 119, 80, 36, 5), 20–26° C (0, 100, 139, 45, 16, 3), 27–41° C (3, 32, 28, 7, 0, 0), and all temperatures pooled (53, 520, 507, 265, 84, 15). We omitted wind–temperature combinations lacking bars (e.g., 20–28 km/hr wind at −5–6° C) from the graph because we had <15 detection trials.

stage, which may be an artifact of our repeated trials at nests because resident owls may have altered their behavior such that detection probability increased due to our repeated visits. Evaluating this possible bias would require that we not visit a subset of nests at all until the later stages of the nesting cycle (something we did not do). However, we do not believe that a change in behavior in response to our repeated nest visits was the reason why detection probability

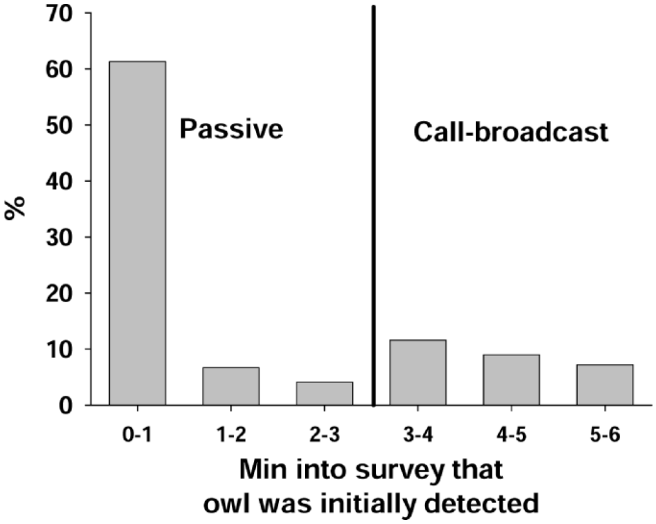

Figure 6. Percentage of burrowing owls initially detected during each of 6 1-minute segments during 1,444 detection trials at 323 nests in northeastern Wyoming and eastern Washington, USA, 2000–2002. The 3 call-broadcast segments began at 3–4 minutes and consisted of 30 seconds of calls followed by 30 seconds of silence.

was higher during the nestling stage. Instead, we believe detection probability was greater later in the nesting cycle because female behavior changed and family size increased as the nesting cycle progressed. Adult females spend a much higher percentage of time above ground during the nestling stage, and ≥1 nestlings are commonly observed at the nest entrance even when neither adult is present.

Although detection probability was greatest during the nestling stage, waiting to conduct surveys when most nests are thought to have nestlings will cause nests that fail prior to hatching to go undetected. Hence, conducting surveys late in the nesting cycle will cause investigators to overestimate reproductive parameters (nesting success, no. of offspring fledged/nest) and underestimate breeding density. Conducting multiple surveys at each point (including one during the early breeding season) would allow observers to locate nests early in the nesting cycle but still detect nests during subsequent surveys (when detection probability is higher) that they missed during the initial survey. Investigators could then base estimates of some reproductive parameters (nesting success, offspring/nesting attempt) on the subset of nests found during the initial survey. Others have suggested 3 or 4 surveys annually (Haug and Didiuk 1993, California Burrowing Owl Consortium 1997, Conway and Simon 2003).

Call-broadcast surveys appeared to increase detection probability of burrowing owl nests even during daylight hours when virtually all of our detections were visual rather than auditory (also see Conway and Simon 2003). Call-broadcast surveys elicited behavioral changes in burrowing owls that increased visual detection (also see Haug and Didiuk 1993). Of the owls detected during the 3-minute call-broadcast segment of trials, we detected most (70%) during the 3 30-second call-broadcast periods, which was also true in southeastern Wyoming (Conway and Simon 2003). Call-broadcast surveys increased detection probability of burrowing owls in southeastern Wyoming by 22%, in eastern Washington by 36%, and in Saskatchewan by 53% where the majority of owls (57%) vocalized during surveys (Haug and Didiuk 1993, Bartels and Tabor 1999, Conway and Simon 2003). One caveat of using call-broadcast surveys for monitoring or research objectives is that raptors can become habituated to recorded calls and response may decline over time (McLeod and Anderson 1998, Watson et al. 1999).

We used call-broadcast surveys to examine factors that influence detection probability of burrowing owl nests. However, use of broadcast equipment introduces a new set of nuisance variables that can vary spatially and temporally among replicate surveys. For example, spatial or temporal variation in equipment quality or broadcast volume might introduce bias into estimates of population change. Passive surveys may detect fewer owls per unit effort but may avoid many of the biases associated with call-broadcast surveys. Our results indicate that use of a survey protocol that includes an initial passive listening segment followed by a call-broadcast segment and recording the number of owls and nests detected during each segment separately allows analysts to control for these biases and takes advantage of the benefits of both passive and call-broadcast surveys.

MANAGEMENT IMPLICATIONS

Detection probability of burrowing owls is affected by a variety of extrinsic factors and such variation should be accounted for when designing a survey protocol for a particular region. We recommend 3 surveys during daylight hours (also see Conway and Simon 2003): one during the timeframe when most owls in the local area are laying or incubating (i.e., 1–30 Apr in WA, and 1–31 May in northeastern WY), another when most owls in the local area have young nestlings (i.e., 1–15 May in WA, and 1–15 Jun in northeastern WY), and a third when most nestlings in the local area will be spending time above ground (i.e., 16 May–15 Jun in WA, and 16 Jun–15 Jul in northeastern WY). Surveys should be conducted when ambient temperature is >20° C and wind speed is <12 km per hour. Most importantly, future studies and future survey efforts should incorporate methods for estimating detection probability so that comparisons can be made across time and space after accounting for differences in detection probability.

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