DOCUMENTING WESTERN BURROWING OWL REPRODUCTION AND ACTIVITY PATTERNS WITH MOTION-ACTIVATED CAMERAS

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ABSTRACT: We used motion-activated cameras to monitor the reproduction and patterns of activity of the Burrowing Owl (*Athene cunicularia*) above ground at 45 burrows in south-central Nevada during the breeding seasons of 1999, 2000, 2001, and 2005. The 37 broods, encompassing 180 young, raised over the four years represented an average of 4.9 young per successful breeding pair. Young and adult owls were detected at the burrow entrance at all times of the day and night, but adults were detected more frequently during afternoon/early evening than were young. Motion-activated cameras require less effort to implement than other techniques. Limitations include photographing only a small percentage of owl activity at the burrow; not detecting the actual number of eggs, young, or number fledged; and not being able to track individual owls over time. Further work is also necessary to compare the accuracy of productivity estimates generated from motion-activated cameras with other techniques.

The Western Burrowing Owl (*Athene cunicularia hypugaea*) is considered a national Bird of conservation concern by the U.S. Fish and Wildlife Service (http://www.fws.gov/migratorybirds/NewReportsPublications/SpecialTopics/BCC2008/BCC2008.pdf) because of declining populations in many parts of its range. Quantifying aspects of reproduction such as number of successful breeding pairs and number of young per successful pair is important to assessing the population's status and trend. Knowledge of the species' activity patterns should be a basis for a sampling protocol and a better understanding of its ecology. Techniques for documenting Burrowing Owl reproduction include counting the number of young outside burrows (Thomsen 1971, Martin 1973, Conway and Simon 2003, Gorman et al. 2003), direct capture (Plumpton and Lutz 1994), video surveillance (Gorman et al. 2003), or observing the birds inside artificial nest burrows (Henny and Blus 1981, Botelho and Arrowood 1998, Belthoff and Smith 2000, Gorman et al. 2003, Todd et al. 2003). Determining activity patterns is usually done by direct observation (Grant 1965, Coulombe 1971, Thomsen 1971), but other techniques such as event recorders (Marti 1974) and radiotelemetry (Haug and Oliphant 1990) have also been used.

These techniques have multiple limitations. Counts at burrows require several visits to ensure detection of all young at a burrow (Henny and Blus 1981, Gleason and Johnson 1985, Gorman et al. 2003). Capturing owls is invasive and capturing all the young may require multiple visits. Video surveillance requires specialized equipment and is time-consuming. Observation inside artificial nest burrows is labor-intensive, and in areas where burrows are not limiting the owls may not occupy them. Documenting activity patterns entails numerous hours of observation by both day and night.

Motion-activated cameras can be set up to take pictures and monitor animal activity for relatively long periods (not continuously) with minimal effort. They have been used to inventory a wide variety of animals in multiple habitats in California (Kucera and Barrett 1993), to identify ground-nest predators (Hernandez et al. 1997), and to monitor burrow use by the Gopher Tortoise (*Gopherus polyphemus*) (Alexy et al. 2003), but they have not been used to study the Burrowing Owl. Because Burrowing Owls live in burrows, frequently enter and exit their burrows, and spend much time around their burrow entrance, the use of motion-activated cameras may be a cost-effective technique to document the species' reproduction and activity patterns. The objectives of our study were to (1) evaluate the use of motion-activated cameras to document Burrowing Owl reproduction and activity patterns, (2) quantify the number of successful pairs and number of young per pair, and (3) describe the owls' activity patterns.

METHODS

Study Area

The Nevada National Security Site (NNSS), formerly known as the Nevada Test Site (e.g., Hayward et al. 1963, Castetter and Hill 1979, Boone et al. 1999) is administered by the U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office (NNSA/NFO). The NNSS encompasses approximately 3561 km^2 in south-central Nevada (Nye County), approximately 105 km northwest of Las Vegas. Despite drastic changes (i.e., craters, denuding of vegetation) to localized areas of the NNSS from testing of nuclear weapons for more than 40 years, biological resources over much of the NNSS remain relatively pristine because only an estimated 7% of the site has been disturbed (U.S. Department of Energy, Nevada Operations Office [USDOE] 1996).

The southern two-thirds of the NNSS is dominated by three large valleys or basins: Yucca, Frenchman, and Jackass flats. Mountain ridges and hills rise above sloping alluvial fans to enclose these basins. Pahute and Rainier mesas and Timber and Shoshone mountains occupy the northern, northwestern, and west-central sections of the NNSS. The site ranges in elevation from <1000 m above sea level on Frenchman and Jackass flats to about 2340 m on Rainier Mesa.

The NNSS has a climate characteristic of high deserts with little precipitation, hot summers, mild winters, and wide diurnal ranges in temperature. Monthly average temperatures range from 7 °C in January to 32 °C in July. The average annual precipitation ranges from 15 cm at the lower elevations to 23 cm at the higher elevations (USDOE 1996). Most of the precipitation falls from December to March in the form of rain or snow; lesser amounts of rain usually fall during July and August. From 1960 to 2005, October to March precipitation as measured on Yucca Flat averaged 10.2 cm, but during our study it varied widely (1998–99, 2.3 cm; 1999–2000, 12.9 cm; 2000–01, 10.1 cm; 2004–05, 22.9 cm).

The NNSS straddles the transition between the Great Basin Desert and the Mojave Desert as defined by Jaeger (1957). Within the site, the vegetation of the Great Basin Desert region is dominated by sagebrush (*Artemisia* spp.), Singleleaf Pinyon (*Pinus monophylla*), and Utah Juniper (*Juniperus osteosperma*), the Mojave Desert region by Creosotebush

(*Larrea tridentata*) and White Bursage (*Ambrosia dumosa*), the Transition region by Blackbrush (*Coleogyne ramosissima*), Nevada Jointfir (*Ephedra nevadensis*), and Burrobrush (*Hymenoclea salsola*).

Camera Setup and Reproduction

We monitored known owl burrows monthly from February to August 1999–2001 and in April, May, and July 2005 to determine if they were active. We considered a burrow active if we found pellets or scat fresh since our previous visit or if we saw an owl at it. We removed pellets or scat during each visit to facilitate identification of fresh sign on the subsequent visit. We included 2005 in the study primarily to compare reproductive success during a very wet year (twice the average) to reproductive success during years with average or below average precipitation and excluded 2005 data from the activity-pattern analysis. At each active burrow we set up a TrailMaster camera system (TM1500 active infrared trail monitor, Goodson & Associates, Inc., Lenexa, KS). The cameras were deployed from 3 June to 9 September 1999, 22 February to 10 August 2000, 25 April to 20 August 2001, and 31 May to 10 August 2005.

Each system (Figure 1) consisted of an infrared transmitter (A), a receiver (B), a weather-resistant 35-mm camera with a protective shelter and mounted to a fence post (C), and a cable connecting the camera to the receiver (D). The beam of infrared light emitted by the transmitter was aimed at a window on the side of the receiver. The transmitter and receiver were set up within 15 cm of the burrow entrance so that the beam projected across the entrance. Each time an owl or other animal interrupted the beam, the receiver recorded the date and time. Depending upon how the camera system was programmed, each interruption could also trigger the camera to take a picture. We set 0.5 sec as the shortest interruption of the beam the receiver would register and 30 min as the minimum interval between photographs. Thus only events at least 30 min apart were photographed. The camera was mounted on a fence post 4 to 6 m from the burrow entrance and aimed at the burrow entrance. Photographs were recorded on 200-speed, 36-exposure Kodak Royal Gold color film. Cameras were equipped with an automatic flash for night pictures.

Once the camera system was in place, we tested the system by manually interrupting the beam of light with a hand or other object and confirming that the camera took a picture. During initial setup at each burrow we recorded the location, date, time, starting picture number, and starting event number. If, when we retrieved the system, the number of pictures taken was ≤10 we left the film in the camera for use at the next site. Thus the maximum number of pictures taken at any one burrow ranged from 25 to 35. The length of time the camera could take pictures at each burrow ranged from a minimum of 12.5 hours (25 pictures taken every half hour) to the entire duration of the setup. Thus for photographs the "sampling effort" was not standard across burrows, being affected by the entry/exit behavior and number of owls at each burrow. Because of the memory-storage limitations of the receiver the maximum number of events that could be recorded was about 1100.

Camera systems were moved to new burrows usually every two to three days. We used a portable data recorder to upload data from the receivers in the field and later downloaded them to a desktop computer. The cameras were set up to print the date and time on the picture, and the times on both the camera and TM1500 receiver were synchronized. The film was processed commercially, and we hand-labeled each picture with the date, time, location, and which individuals were in the picture. From these pictures we determined the numbers of adults and young, but we did not attempt to age the young. We defined a pair as successful if we detected one or more young at their burrow, as nonproductive if we detected no young. We also recorded species other than the Burrowing Owl.

Activity Patterns

To investigate daily activity patterns defined as presence of owls on the burrow apron and entry into or exiting from the burrow entrance, we examined the photographs and associated event data for 1999–2001. Our objectives for the analysis of activity patterns were to determine (1) times when owls were present around their burrow entrance, (2) differences in activity patterns between young and adults, and (3) the best times to count the maximum number of young per nest burrow.

To upload all data from the receivers (date, time, event number, photograph number) to a computer, we used StatPack software (Goodson & Associates, Inc., Lenexa, KS). We described the content of each photograph, categorizing the photo by whether it included (1) adult owl(s), (2) young owl(s), and (3) the maximum number of young owls at that burrow. These data were imported into a Microsoft Excel spreadsheet, in which we plotted the number of photographs containing the various contents listed above for each hour of the day. We assigned each photograph a whole-hour value; for example, a photograph taken between 02:00 and 02:59 was assigned the whole-hour value of 02:00. We used a chi-squared analysis of each category to assess whether activity patterns differed from that expected if activity were random. We then modeled the counts as Poisson random variables and used harmonic analysis to identify peaks in activity.

RESULTS

A total of 2828 photographs were taken from 1999 to 2001. Of these, 2225 (79%) contained pictures of owls, 406 (14%) contained pictures of animals other than owls, and 197 (7%) detected no animals. Over the four breeding seasons, we detected 37 successful breeding pairs and 180 young with an average of 4.9 young per successful pair (Table 1). We also documented ten pairs with no young, one in 1999, two in 2000, three in 2001, and four in 2005. Including these ten lowers the average to 3.8 young per pair. Over all years combined, breeding was successful at 20 of the 45 sites (44%) sampled. We sampled burrows photographically from one to seven times (generally two to four) per year, depending on how long a burrow remained active. Of the 406 photographs of animals other than owls, 22 (5.5%) were of Burrowing Owl predators, including seven photos of the Kit Fox (*Vulpes macrotis*), six of the Badger (*Taxidea taxus*), three of the Coyote (*Canis latrans*), one of a Bobcat (*Lynx rufus*), three of the Common Raven (*Corvus corax*), one of a Greater Roadrunner (*Geococcyx*

Figure 1. TrailMaster (TM1500) camera system set up at a burrow (A, transmitter; B, receiver; C, camera and protective shelter; D, cable).

Photo by Derek B. Hall

californianus), and one of an unknown raptor. The remaining photographs were of rabbits, rodents, and passerines. The rate of predator visitation we detected was low, but our technique was not able to detect predators such as snakes. No instances of predation were photographed.

Adult owls were detected on their burrow's apron during all hours of the day and night (Figure 2) and the result of the chi-squared test was significant ($\chi^2 = 80$, $P < 0.001$). Harmonic analysis revealed two peaks of activity, one in the morning between 07:00 and 08:00 and another in the late afternoon between 16:00 and 17:00 (Figure 2). Young owls were also detected on their burrow's apron during all hours of the day and night (Figure 3), and the result of the chi-squared test for them was also significant ($\chi^2 = 131$,

Table 1 Productivity of Burrowing Owls as Detected by Motion-Activated Camera at the Nevada National Security Site

	Sites sampled	Breeding pairs	Young owls	Young per pair	Range	Standard deviation
1999	18	7	24	3.4	1–6	1.6
2000	24	8	43	5.4	3–8	1.6
2001	23	11	55	5.0	1–8	2.1
2005	18	11	58	5.3	3–8	1.7
Total	45[a]	37	180	4.0	1–8	1.9

[a]Number of unique sites; some sites were sampled in multiple years.

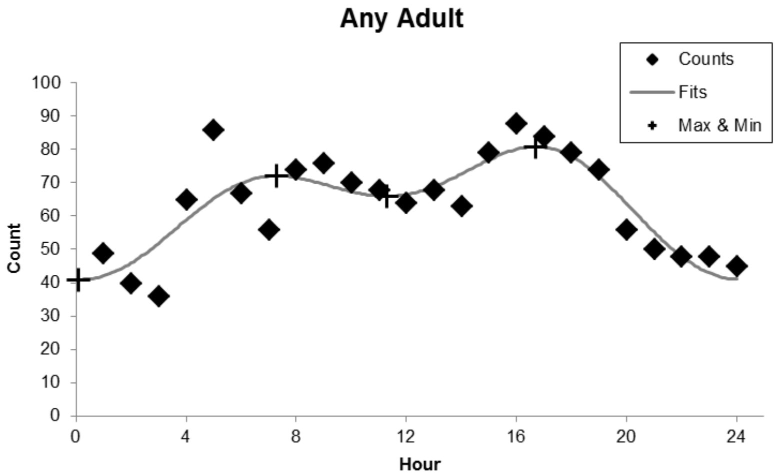

Figure 2. Number of photos with adult owls by time of day at the Nevada National Security Site, 1999–2001 (n = 1533). Curve represents results of harmonic analysis.

P < 0.001). Again, the harmonic analysis showed two peaks of activity, one in the morning between 07:00 and 08:00 and another in the evening between 18:00 and 19:00 (Figure 3). The maximum number of young owls per nest burrow was documented during most but not all hours of the day and night (Figure 4), and the result of the chi-squared test of this variable was again significant ($\chi^2 = 94$, $P < 0.001$). Like that for detection of any young,

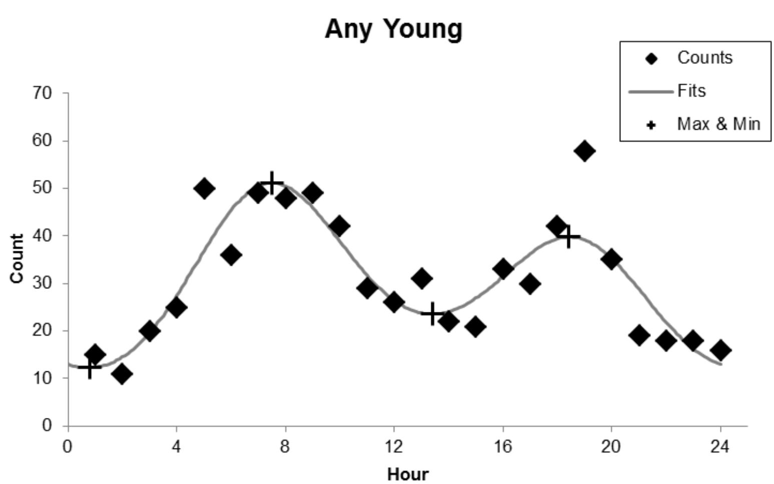

Figure 3. Number of photos with young owls by time of day at the Nevada National Security Site, 1999–2001 (n = 743). Curve represents results of harmonic analysis.

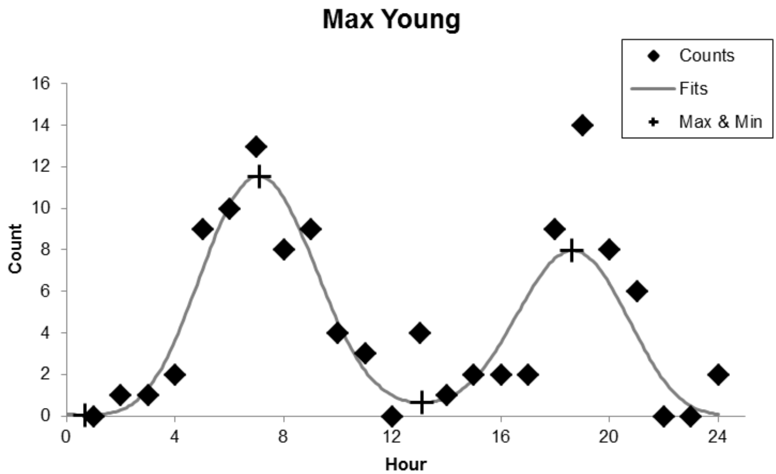

Figure 4. Number of photos when the maximum number of young Burrowing Owls per nest burrow was detected by time of day at the Nevada National Security Site, 1999–2001 (n = 110). Curve represents results of harmonic analysis.

harmonic analysis of records of the maximum number of young showed two peaks, between 07:00 and 08:00 and between 18:00 and 19:00 (Figure 4).

DISCUSSION

Motion-activated cameras set up at burrows documented the Burrowing Owl's reproduction and activity patterns. The actual number of young fledged at each burrow monitored was not known, so it is not possible to determine how accurate this technique was in revealing all young at a burrow. Future study should compare counts of young with motion-activated cameras to the known number of young in artificial nest boxes as exemplified by Gorman et al. (2003). Only two to four visits to a burrow (one to three camera setups plus one visit to determine if the burrow is active) are required to document young at an active burrow, which is one to three fewer visits than recommended by Gorman et al. (2003). With a film camera, up to 35 observations can be recorded over an 18-hour period (photographs taken every half hour,, including at night). Digital cameras can now be used to capture several hundred photographs per setup at an increased frequency (e.g., one every minute) if desired, increasing the number of photographs available for refining activity patterns, including timing of prey delivery and feeding. Infrared light sources could also be used instead of camera flash to minimize disturbance to owls at night. Additionally, cheaper video cameras are now available and could be used to document activity patterns and behavior.

The average numbers of young per successful pair and per pair (including nonproductive pairs), 4.9 and 3.8, respectively, were within the range of values previously reported from the western United States (Thomsen

1971, Martin 1973, Smith and Murphy 1973, Gleason and Johnson 1985, Belthoff and King 1997, Botelho and Arrowood 1998, Lutz and Plumpton 1999, Belthoff and Smith 2000). Because we sampled throughout the breeding season and didn't track survival of chicks, we do not know how many of the young detected photographically actually fledged. Thus our values are most likely inflated. Timing of camera setups should be standardized at specific times through the breeding season for the number fledged per pair to be determined. The number of young per successful breeding pair varied by year (Table 1), but the differences were not statistically significantly (F = 1.86, df = 3, P = 0.156). Precipitation from October to March prior to the breeding season was well below average during 1998–1999 and average to more than double the average during the remaining years. Precipitation during this period is positively correlated with the abundance of desert vertebrates (Beatley 1969, Munger et al. 1983, Nagy 1988, Saethre 1994, Sowell and Boone 1996) and may partially explain the low number of young per breeding pair during 1999. The correlation between owl productivity and precipitation warrants further study.

The owls we studied were active during all hours of the day and night with peaks of activity in the morning and evening. Although the harmonic analysis showed the morning peak for both adults and young to be between 07:00 and 08:00, another spike of activity occurred between 05:00 and 06:00. In Colorado, Marti (1974) also found the Burrowing Owl to be active in every hour of the day and night with activity distributed trimodally. The peaks of activity he reported differed somewhat from ours and included one of about five hours centered around sunrise, one of two hours just before midday, and another five-hour period centered around sunset. In Minnesota, Grant (1965) concluded that activity was concentrated in early morning and late evening, with little activity during the day. In California, Thomsen (1971) reported that between 12:00 and 16:00 owls were little in evidence but came out to the burrow apron in late afternoon.

Although we detected both young and adult owls at the burrow entrance at all times throughout the day and night, adult owls were detected more frequently than young during the afternoon and early evening. In California, Coulombe (1971) reported that young owls were frequently outside during the morning and afternoon but rarely during midday.

The best times to detect the maximum number of young owls at nest burrows were from 05:00 to 10:00 and from 18:00 to 21:00, so visual surveys at these times should maximize the probability of detecting the greatest number of young at the NNSS.

During our study, the date of the start of camera monitoring varied considerably from year to year: 3 June 1999, 22 February 2000, 25 April, 2001, and 31 May 2005. However, the earliest dates that young were detected were 26 June 1999, 18 May 2000, 31 May 2001, and 2 June 2005, and the vast majority of young were detected during June and July (Hall et al. 2003). Although some nonproductive pairs may have been missed, it is unlikely that any young were missed. Similarly, in southwestern Idaho Belthoff et al. (1995) reported that the first young owls appeared above ground on 20 May 1994, and they concluded that most young were hatched between mid-May and early June. In south-central Idaho, Rich (1986) observed young near natal burrows as early as 10 June and as late as 17 September. From the size and plumage of the young in the photographs, we believe that reproduction in 1999 was delayed in comparison to that in 2000, 2001, and 2005. The delay was possibly caused by the late arrival of precipitation (5 cm in late April), which is necessary for stimulating plant growth and rodent reproduction (Beatley 1969). Results from Burrowing Owl trapping at the NNSS in 2007 (a very dry year) also indicated delayed reproduction (National Security Technologies 2008). In Arizona trapping showed late breeding and many failures in 2007 also (Vicki Garcia pers. comm.). In contrast, in Canada Wellicome (2005) found that Burrowing Owls do not adjust their egg laying on the basis of food supply. Perhaps in desert ecosystems Burrowing Owls have adapted a more conservative approach to reproduction in response to a more variable prey base due to limited, sporadic moisture. More study across geographic regions is required to determine if this is true. On the basis of our data, we recommend that researchers using motion-activated cameras in similar habitats set up cameras from mid-May through mid- to late August to document owl reproduction.

We encountered two problems while using the TM1500 system. The most common problem was owls and other birds perching on the camera shelter and tipping the camera so it was no longer focused on the burrow entrance. To fix this problem we taped the camera shelter to the fence post with duct tape. Another problem was rodents or other animals chewing through the cable that connected the camera to the receiver. This was remedied by burying the cable 2.5 to 5 cm under ground and using duct tape to cover the first 30–60 cm of the cable next to the fence post. It is advisable to have two or three extra cables on hand.

Only about half of the active burrows surveyed were productive. At some sites, photographs documented a pair of adults but no young. We considered these pairs nonproductive. Reasons for pairs being nonproductive could have been failure to breed or failure of the nest from factors such as nonviable eggs or predation. Also, sometimes photographs disclosed older juveniles later in the season at sites where photographs from previous months' sampling had not revealed any young. We did not consider these sites nest burrows, inferring that the owls had relocated to these burrows later in the season. At some sites, one adult owl and no young were detected in the photographs. At many active burrows, no owls were photographed, suggesting only short-term occupancy of these burrows (e.g., owls migrating through the area or searching for a suitable burrow). The use of motion-activated cameras did not appear to cause Burrowing Owls to abandon their burrows.

Using motion-activated cameras to document successful owl reproduction and activity patterns requires fewer visits to burrows than do direct observations, is less invasive than capturing the birds, is less time-consuming and less expensive than video surveillance, and requires much less time and effort than direct observations. This technique requires less labor than installation of artificial burrows, and natural burrows may have a higher chance of being occupied than artificial burrows, especially in areas where burrows are not limiting. Limitations of motion-activated cameras with film include photographing only a small percentage of owl activity at the burrow; not detecting the actual number of eggs, young, or number fledged; and not being able to track individual owls over time. Using digital cameras to take photographs more frequently would help overcome the first limitation but would also increase the processing time. Future studies should examine how accurate motion-activated cameras are in quantifying the number of young in comparison to the known number of young in artificial nest boxes or observed directly in natural burrows. Studies investigating factors that influence reproduction, including precipitation, predation, and disease, are also needed.

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