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## Post-Breeding Dispersal of Burrowing Owls in an Extensive California Grassland

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**ABSTRACT.**—Understanding patterns of dispersal is key to developing effective conservation plans, yet dispersal is poorly known for most species. We radio-tracked 15 adult burrowing owls (*Athene cunicularia*) from 13 nests within the Carrizo Plain National Monument in southern California. Our goal was to describe post-breeding movements in this extensive grassland system. Of nests that failed ( $n = 9$  nests), 8 radio-tagged individuals from 7 nests dispersed, whereas none of the owls from successful nests ( $n = 4$  nests) dispersed. Dispersal distances ranged from 0.2 km to 53 km (median = 3.1 km). The large dispersal distances we observed within the breeding season were greater than previously published estimates of between-year breeding dispersal based on mark-recapture methods and provide insight into the lack of genetic differentiation observed among burrowing owl populations.

### INTRODUCTION

Burrowing owl (*Athene cunicularia*) populations have declined in some portions of their range (Klute *et al.*, 2003) and reintroduction of populations has been considered (Leupin and Low, 2001, Martell *et al.*, 2001). Despite this, little is known of patterns of dispersal, either in highly modified systems or in larger more intact grassland ecosystems. Few estimates of dispersal distributions of adult burrowing owls exist despite their importance in the dynamics and spatial distribution of their populations (Haug *et al.*, 1993; Millsap and Bear, 1997; Catlin, 2004).

Dispersal distributions are subject to bias if the study area is too small relative to distances that individuals travel (Koenig *et al.*, 1996). Increasing the size of the study area through the use of secondary and super study-sites and the use of radio telemetry have been suggested as methods to overcome the problems associated with using re-observations of marked animals to estimate dispersal (Koenig *et al.*, 1996). Burrowing owls are difficult to re-observe following extensive movements, and the study areas of most researchers are small. Consequently, their dispersal potential is virtually unknown.

Burrowing owls in non-migratory populations often do not display breeding dispersal, but rather re-nest within the same nest burrow or relocate to a nearby burrow. The majority of owls in some ecosystems reuse nest sites from year to year (Rosenberg and Haley, 2004). In an urban environment in Florida (Millsap and Bear, 1997) and in an agricultural system in California (Catlin, 2004; Rosenberg and Haley, 2004), few adult owls dispersed >400 m between breeding seasons. Interestingly, densities of burrowing owls were exceptionally high at these sites. Few estimates of breeding dispersal have been reported in large expanses of continuous habitat with lower population densities. We hypothesized that dispersal distance

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during the breeding season, which entails movement from one nest to another, would be greater in such environments, and this would be likely to occur following nest failure. To describe dispersal patterns within the breeding season, we examined post-breeding movements of adult burrowing owls using radio telemetry in a large expanse of non-fragmented grassland in southwest California.

#### METHODS

We studied a non-migratory population of burrowing owls within and adjacent to the Carrizo Plain National Monument (hereafter, Carrizo), located approximately 80 km southwest of Bakersfield, California, USA (35°11'N, 119°52'W). Carrizo includes approximately 100,000 ha that is jointly managed by the Bureau of Land Management, California Department of Fish and Game and The Nature Conservancy. Carrizo is the largest remaining tract of San Joaquin Valley grassland (Schiffman, 2000) and is a broad plain bordered by the Caliente Mountains to the southwest and the Temblor Mountains to the northeast. This region has a semi-desert climate receiving an average annual rainfall of 15 cm (Williams, 1992). Non-native grasses, dominated by foxtail (*Vulpia sp.*), bromes (*Bromus sp.*), filaree (*Erodium cicutarium*) and oats (*Avena sp.*), are the predominant vegetation in the plain, though there are also remnant patches of native vegetation such as common saltbush (*Atriplex polycarpa*), spiny saltbush (*Atriplex spinifera*), nodding needlegrass (*Nasella cernua*), iodine bush (*Allenrolfea occidentalis*) and blue grass (*Poa secunda spp. secunda*). Native annuals such as lupine (*Lupinus sp.*), goldfields (*Lasthenia sp.*) and owl's clover (*Castilleja sp.*) are also present (Butterworth and Chadwick, 1995; Ronan, 2002).

We located burrowing owl nests from April to May 2000 using three methods: re-observation of known locations of nests found during surveys conducted in 1996 to 1999, incidental discoveries and nocturnal call surveys. Call surveys consisted of broadcasting the territorial call at stations along vehicle-accessible roads between 19:30 and 03:00 h (Haug and Didiuk, 1993; Ronan, 2002; Conway and Simon, 2003). We conducted nest searches early in the breeding season to locate first nesting attempts. We captured owls using bow nets and burrow traps at nests (Rosenberg and Haley, 2004) from mid-April through May 2000. We outfitted male and female owls with necklace design radio transmitters (4.6 g) that included a 20 cm antenna, with a 24-wk expected battery life (Holohil Systems, Ltd., Carp, Ontario, Canada), following methods described by Gervais *et al.* (2003).

After release, we searched for radio-collared owls every 7–9 d from May through July 2000. We conducted ground searches with a hand held 'H' antenna and a truck-mounted yagi antenna system (Gervais *et al.*, 2003). We searched for owls not detected from ground searches with biweekly flights of fixed-wing aircraft. We used a broad transect pattern (approximately 1.0 km apart) at an elevation of 250–450 m above ground to cover large areas of suitable habitat. Additionally, we searched areas of suitable habitat adjacent to the Carrizo. The search area, which was covered at least once during the season, included all of the grasslands and foothills of the Carrizo and the surrounding area, with a total search area of approximately 3500 km<sup>2</sup>. When an owl was relocated during a flight, we initiated a ground search of the area following the flight to confirm the location and status of the owl. Status categories were alive, dead, or re-nesting.

We defined within-season breeding dispersal as movement within the breeding season to a second nest greater than 100 m from the first nest burrow. We used 100 m as the basis for quantifying dispersal because family movements and neighboring ("satellite") burrows are typically within this distance (Desmond and Savidge, 1999; Ronan, 2002). We attempted to confirm re-nesting following relocation through observations of owl behavior, nesting sign and underground nest observations using an infrared probe (Sandpiper Technologies, Inc.,

Manteca, California). However, we were not able to confirm re-nesting in all cases and, thus, our definition of breeding dispersal may include movements that are not truly breeding dispersal events. We defined dispersal distance as the shortest distance from the first nest to the second burrow or nest location.

#### RESULTS

We captured and radio-tracked 15 burrowing owls from 13 nests: four females and 11 males. By the end of the study, we found four (27%) of the radio-marked owls dead during the study, confirmed six (40%) owls alive and the status of five (33%) was unknown. Male owls that died were recovered from 0.5 to 1.6 km (mean = 0.9 km) from their nest; we assumed these deaths occurred during foraging or other exploratory movements as they were not recovered at burrows. The only female recovered dead during the study was exhumed from a burrow approximately 5 m from the nest burrow, apparently from natural collapse of the burrow.

Dispersal was strongly influenced by nest success. Of the 13 nests in our sample, 9 (69.2%) failed. After nest failure, the radio-tagged owls ( $n = 6$  males and 2 females) from 7 of the 9 nests (77.7%) dispersed and were relocated at least once during the study. Dispersal distance ranged from 0.2 km to 53.1 km and averaged  $14.9 \pm 8.3$  km, with a median of 3.1 km (Fig. 1). Of the two nests for which both the male and the female were radio-tagged, both nests failed. In one of these cases, both individuals dispersed and were located 2.1 km apart, approximately 2.1 (female) and 1.1 km (male) from their original nest. In the second case, the male remained at the original nest, but the female dispersed 4.1 km. We confirmed re-nesting at the second burrow location for three of the owls; we were unable to verify nest status of the remaining five owls.

#### DISCUSSION

Adult burrowing owls in our study dispersed much greater distances during the breeding season than we expected. We recorded two long-distance movements of over 53 km. The location of five additional owls was unknown by the end of the study and it is possible dispersal distances of these owls exceeded our ability to detect them as our maximum detection distance was approximately 60 km. Although long distance movements of dispersing juvenile owls have been observed between breeding seasons (Wellicome *et al.*, 1997), movement of this magnitude of adults, especially of males, within the breeding season was not anticipated. Wellicome *et al.* (1997) reported 49 km as the maximum dispersal distance detected between breeding seasons for adult burrowing owls in Saskatchewan, Canada, and suggested the large distances may be due to fragmentation of rangeland habitat. Our results suggest fragmentation itself may not be responsible. Using similar field and analytical methods, dispersal distances within the breeding season were much greater at our study site, a non-fragmented grassland, than at an intensively agricultural site (Catlin, 2004). Other factors, such as density of owls and high predation levels, may be the primary determinants of dispersal differences among habitat types (Catlin, 2004). Our results, in comparison to low dispersal distances in high density owl populations in California (Catlin, 2004; Rosenberg and Haley, 2004) and Florida (Millsap and Bear, 1997), support this hypothesis. Burrowing owl breeding and natal dispersal may be much greater than previously believed and may explain the lack of genetic differentiation among western North American populations (Korfanta, 2001). Results from stable isotope analyses provide further support for long distance movements of burrowing owls (Duxbury, 2004).

Movement of owls was associated with nest failure, which was high during our study and

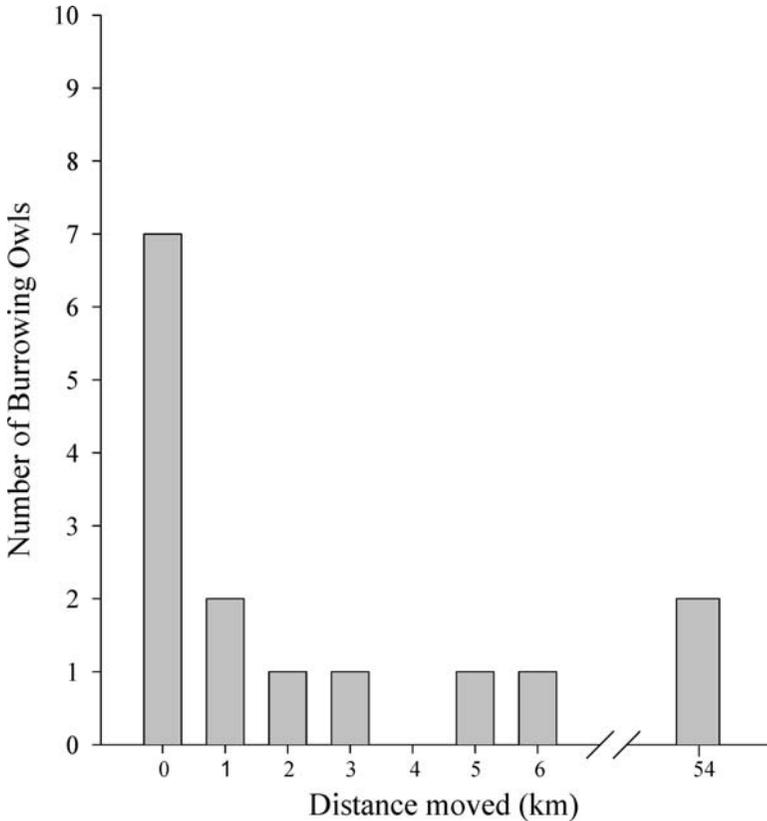


FIG. 1.—Frequency distribution of dispersal distances of burrowing owls within the breeding season on the Carrizo Plain, California. Zero distance moved indicates that the owl remained at the first nesting site

variable among years within the Carrizo Plain (Ronan, 2002). Our results support Newton's (1979) assertion that raptors are more likely to move to a new nest site if the first clutch fails, consistent with the avian literature (reviewed in Greenwood and Harvey, 1982) and burrowing owls (Catlin, 2004) in particular. Recent experimental evidence demonstrates that predation increases dispersal probability (Haas, 1998; Catlin, 2004) and even the risk of predation may increase dispersal distances (Hakkarainen *et al.*, 2001), suggesting that breeding dispersal may be a mechanism for avoiding future nest predation. Our data suggest that dispersal within the breeding season following nest failure is common in burrowing owls and that nest failure may be a significant factor initiating breeding dispersal (Haug *et al.*, 1993; Catlin, 2004; Rosenberg and Haley, 2004).

We believe our results on burrowing owl movements primarily represented within-season breeding dispersal rather than exploratory movements or responses to radio-transmitters. Re-nesting was attempted following dispersal in several cases and at least one owl that moved 5 km and re-nested during the 2000 breeding season nested at the new location in the following year (D. K. Rosenberg, pers. obs.). However, in some cases we were unable to confirm nesting and thus the distances we observed may only represent partial breeding

dispersal. Although we have found evidence of reduced survival rates of owls with radio-transmitters (Gervais *et al.*, *in press*), dispersal distances do not seem affected by radio-transmitters. Catlin (2004) found similar dispersal distances between burrowing owls with radio-transmitters and those with only color bands.

Our findings provide support for several concerns regarding estimates of survival and population declines of burrowing owls that are based on occupancy of historical nest sites. First, emigration interjects bias into estimates of survival from single-site mark-recapture models even within large study sites. At a minimum, it will be important to evaluate the likelihood of emigration from a given study area using observed movement rates (Koenig *et al.*, 1996; Frederiksen and Bregnballe, 2000; Rosenberg and Haley, 2004; Winkler *et al.*, 2004). Second, our results suggest that simply examining the historical nesting burrows of burrowing owls to evaluate declines may be misleading. Extensive movements following nest failure or mate loss will lead to low occupancy rates of previously occupied nest sites independent of changes in population size (Ronan, 2002). Because of the large temporal variation in nesting success, breeding dispersal may be particularly common in some years. This may lead to incorrect conclusions about declines based on occupancy rates of historical locations or nests.

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