Biology Faculty Publications and Presentations

Department of Biological Sciences

2-1-2001

Post-Fledging Dispersal of Burrowing Owls in Southwestern Idaho: Characterization of Movements and Use of Satellite Burrows

R. Andrew King
Boise State University

James R. Belthoff
Boise State University

POST-FLEDGING DISPERSAL OF BURROWING OWLS IN SOUTHWESTERN IDAHO: CHARACTERIZATION OF MOVEMENTS AND USE OF SATELLITE BURROWS[1]

R. ANDREW KING[2] AND JAMES R. BELTHOFF[3]

Department of Biology and Raptor Research Center, Boise State University, Boise, ID 83725

Abstract. Using radiotelemetry, we monitored dispersing juvenile Western Burrowing Owls (*Athene cunicularia hypugaea*) within a migratory population in southwestern Idaho during 1994 and 1995. Owls remained within natal areas for an average (± SE) of 58 ± 3.4 days post-hatching before moving permanently beyond 300 m, which was our operational cutoff for dispersal from the natal area. On average, owls dispersed on 27 July (range: 15 July to 22 August), which was approximately 4 weeks after fledging. After initiating dispersal, juveniles continued moving farther away from their natal burrows and, by 61–65 days post-hatching, they had moved 0.6 ± 0.2 km. Each juvenile used 5.1 ± 1.2 satellite burrows, and individual satellite burrows were used for up to 14 days. The average date on which we last sighted radio-tagged juveniles was 13 August, and all but one juvenile departed the study area by early September. Our study illustrates the importance of satellite burrows to dispersing Burrowing Owls.

Key words: Athene cunicularia hypugaea, *post-fledging dispersal, radiotelemetry, satellite burrow, Western Burrowing Owl.*

INTRODUCTION

When juvenile birds permanently move away from their natal area, they begin a process often referred to as natal dispersal. Dispersal typically begins shortly after young gain independence from parents and continues until first breeding commences. The dynamics of dispersal of migratory species may differ from those of resident species because of the temporal discontinuity imposed by migration to a wintering area (Morton et al. 1991, Morton 1992). In migratory species, final dispersal may consist of movements both before (post-fledging) the initial migration and after returning to breeding grounds. Therefore, it is helpful to distinguish among various stages of the dispersal process and to recognize that each stage may vary in length, continuity, and relative importance among species. In this study, we examined post-fledging dispersal of juveniles in a migratory population of Western Burrowing Owls (*Athene cunicularia hypugaea*; henceforth Burrowing Owls) in southwestern Idaho. We considered post-fledging dispersal to include movements juveniles make away from natal areas (usually after gaining independence

from adults) prior to and leading up to autumn migration.

Burrowing Owls are widely distributed among open, well-drained grasslands, steppes, deserts, prairies, and agricultural lands in western North America (Haug et al. 1993). In recent decades, and in contrast to increases in Florida Burrowing Owls (*A. c. floridana,* Millsap and Bear 1997), many populations throughout western and midwestern North America have declined (James and Espie 1997, Sheffield 1997), especially in Canada (De Smet 1997, Kirk and Hyslop 1998). Thus, avian biologists and resource agencies throughout North America have understandable concern about the status of this species. Quantifying and understanding aspects of the movement biology of these birds is critical for developing comprehensive management or species recovery plans.

Most studies of dispersal in Burrowing Owls have been limited to re-encounters at nest sites of owls banded as juveniles (De Smet 1997, Wellicome et al. 1997, Lutz and Plumpton 1999). These studies provide important information about ultimate dispersal distances (distance between natal and first breeding sites, i.e., natal dispersal distances) and rates of philopatry (return of owls to nest sites or study areas), but they offer little or no insight into behavior of juveniles during the post-fledging period or upon return to study areas after migration. The objec-

[2] Present address: BHE Environmental, Inc., 11733 Chesterdale Road, Cincinnati, OH 45246.
[3] Corresponding author. E-mail: jbeltho@boisestate.edu

tive of our study, therefore, was to document and describe post-fledging dispersal behavior and movements of juvenile Burrowing Owls prior to their first migration. Movements during this period constitute the initial stage of the natal dispersal process (Morton 1992, Belthoff and Dufty 1998, Dufty and Belthoff 2000) or, as in some White-crowned Sparrows (*Zonotrichia leucophrys*) for example, the entire natal dispersal process (Morton 1992). We summarize timing, distance, rate, and direction of post-fledging dispersal movements. Although Burrowing Owls rely on satellite burrows (non-nest burrows) near their nests, few studies characterize their use away from the nest area or at other times in the annual cycle. Therefore, our second objective was to quantify use of satellite burrows by juvenile Burrowing Owls during the dispersal process.

METHODS

STUDY AREA

During 1994 and 1995, we studied Burrowing Owls nesting in and near the Snake River Birds of Prey National Conservation Area in southwestern Idaho. This area (formerly Snake River Birds of Prey Area) is more than 196,000 ha in size and was established in 1993 by Congress (Public Law 103-64) to provide for conservation, protection, and enhancement of raptor populations and habitats. Although land use in the area is varied (including grazing, agriculture, recreation, military training, residential areas, and power generation), the area contains an exceptionally high diversity of raptors. Fifteen species nest in the Snake River Canyon or in surrounding uplands, including Burrowing Owls, and another 10 species use the area during migration or in winter (U.S. Department of the Interior 1996). Our core study area (approximately 5 km^2 in which owls nested) was located approximately 30 km southwest of Boise, Ada County, Idaho (43°26′N, 116°23′W). Once owls initiated dispersal, we also searched the surrounding areas and up to 80 km in each direction.

Vegetation is characteristic of disturbed sagebrush (*Artemisia tridentata*) steppe with predominately xeric species. Fire and other disturbances have converted much of the native shrublands into disturbed grasslands dominated by cheatgrass (*Bromus tectorum*), tumble mustard

(*Sisymbrium altissimum*), and other mostly non-native species of grasses and forbs. These habitat changes appear to benefit Burrowing Owls, as these birds prefer areas with sparse vegetation and short grass to dense sagebrush. Surrounding areas contain irrigated agricultural fields (primarily alfalfa, mint, and sugar beets), a sewage treatment facility with associated effluent fields, scattered residential homes, dirt, gravel, and paved roads, rangelands managed by the Bureau of Land Management, and several dairy farms. Burrows, excavated mainly by American badgers (*Taxidea taxus*), are abundant in the study area because it contains one of the densest populations of badgers in North America (Messick 1980). Burrowing Owls used these abandoned burrows for nesting and shelter throughout the spring and summer.

Burrowing Owls appear to be annual migrants in southwestern Idaho, given that we have observed very few owls during winter in the core study area. During both 1994 and 1995, we first observed owls in mid-March during surveys initiated earlier in winter. Migration routes and wintering areas for owls breeding in our study area generally remain unknown, although two recent (1997–1999) band returns indicate that at least some Idaho birds winter in or migrate through southern California (J. Belthoff, unpubl. data).

LOCATING AND CAPTURING BURROWING OWLS

We located nests by searching suitable habitat and historical nesting areas while on foot and from an automobile, after which time we monitored nesting owls almost daily. We captured juvenile Burrowing Owls (1) using double-door Havahart® live traps (Woodstream Corp., Lititz, Pennsylvania) placed in or near burrow entrances during the nestling period (12–30 days), (2) with noose-rods and carpets placed in front of nest burrows, (3) by hand near the entrance of burrows, often after sneaking up on unsuspecting owlets, and (4) using a basket trap made of chicken wire and equipped with a one-way door. We considered number of juveniles captured at nest sites to represent minimum reproductive output of the pair, because some juveniles may have gone undetected, even though we repeatedly trapped at each nest burrow throughout the nestling period. Juvenile owls sometimes move on foot to other nest burrows (Henny and Blus

1981, Johnson 1997), so our estimates of reproductive output for pairs are based on number of young cared for and may not represent the pair's genetic contributions to the population. Colorbanded owls (banded as early as 12 days after hatching) in this study were never observed in a nest of another pair.

MARKING AND RADIO-TRACKING

Upon capture, we estimated age of each juvenile based upon degree of feather development (Landry 1979), relative size, and two unpublished photographic keys. Juvenile Burrowing Owls are sexually monomorphic in size and plumage (Haug et al. 1993); therefore, we were unable to determine sex of juvenile owls during this study. Each owl was color-banded for visual identification in the field.

We placed radio transmitters (Wildlife Materials, Inc., Carbondale, Illinois) on up to three young owls per brood in 1994 and on one randomly selected juvenile per brood in 1995. Approximately half of radio-tagged juveniles received daily food supplements as part of a simultaneous experiment; these owls are not included in this study, because the additional food significantly affected dispersal behavior. To control for daily visits to provide supplemental food to juveniles in that study, we also made daily visits to the vicinity of nests reported upon here. We assume these visits had minimal if any effects on behavior of young owls, because we visited during the inactive daytime period. Published studies from Colorado also indicate that disturbances such as regular vehicular traffic have little impact on behavior of nesting Burrowing Owls and no effect on productivity (Plumpton and Lutz 1993).

Approximately one week prior to fledging or when body mass was approximately 100 g, we attached transmitters to juveniles using backpack harnesses made from woven nylon cord (2 mm in diameter). The expected battery life of transmitters was approximately 150 days, which was well beyond the timing of our final sightings of juvenile owls; this limits the likelihood that lost contact resulted from radio failure rather than movement of owls out of the study area. Total weight of radio transmitters with harnesses was less than 4 g (approximately 3% of body mass at fledging, i.e., 135–150 g), and radios had no obvious negative effects on behavior of owls (Haug and Oliphant 1990, pers. observ.).

We tracked owls using hand-held receivers and two-element Yagi antennas (Telonics, Inc., Mesa, Arizona).

We attempted to measure the distance (m) from each radio-tagged juvenile's natal burrow to its diurnal roost site (typically a "satellite" burrow, i.e., a non-nest burrow used for roosting, cover, or caching prey) each day until it departed the study area. However, we were unable to locate the entire sample of radio-tagged owls on some days. We obtained an average of 36 observations on each owl between 26 days of age and until losing radio contact ($n = 166$ observations of four owls in 1994, and 302 observations of nine owls in 1995). We measured shorter distances (<500 m) with a 50-m fiberglass tape and longer distances using calculations of locally adjusted Universal Transverse Mercator (UTM) coordinates obtained from a portable Global Positioning System (GPS) receiver, 7.5-min USGS topographical maps, and aerial photographs of the study area. When we no longer could locate dispersing owls from the ground, aerial searches were conducted from a single-engine airplane equipped with radio-telemetry gear and a GPS receiver ($n = 5$ searches between 26 July and 19 October of both years). Aerial searches covered hundreds of square kilometers in all directions from the core study area. When owls were detected from the air, we attempted to confirm their locations during follow-up ground searches (all but 20 [4.3%] observations are based on visual sightings of individuals). We assumed that if we no longer could locate radio-tagged owls based on ground or aerial searches, they had initiated fall migration. We also surveyed the study area through the end of summer and into autumn to confirm that radio-tagged and otherwise color-banded owls departed. The concurrent disappearance of color-banded (without radios) owls supports our assumption that owls initiated migration when radio-signals were lost. We considered each juvenile's dispersal direction as the compass bearing originating from the natal burrow to its last known location prior to fall migration.

Our working definition of "dispersal from the natal area" was a permanent movement >300 m away from the natal burrow. We based this cutoff distance for defining when a juvenile had dispersed upon observations during our initial year of study (1994). In that year (and in subsequent years that we have monitored dispersing

TABLE 1. Annual means (± SE) of various measurements of radio-tagged juvenile Burrowing Owls during the 1994–1995 breeding seasons in southwestern Idaho. Dates were standardized using the Julian calendar. We recorded age as days post-hatching estimated initially by morphological characteristics at time of capture.

Variable	1994 (n = 4)	1995 (n = 9)	1994–1995 (n = 13)
Hatch date[a]	24 May ± 5.4	2 June ± 4.4	30 May ± 3.6
Brood size[b]	5.5 ± 0.5	5.7 ± 0.5	5.6 ± 0.4
Age when first observed away from natal burrow (days)	32.3 ± 4.5	38.7 ± 2.2	37.1 ± 2.0
Age when last observed at natal burrow (days)	43.3 ± 9.8	40.2 ± 2.8	41.0 ± 3.0
Distance to first satellite burrow (m)	44.0 ± 15.9	98.9 ± 20.9	82.0 ± 16.6
Distance to last satellite burrow prior to dispersal (m)[c,d]	150.2 ± 39.7	161.4 ± 23.5	158.0 ± 19.4
Satellite burrows used prior to dispersal	3.8 ± 0.6	2.3 ± 0.4	2.8 ± 0.4
Age at dispersal (days)	69.3 ± 3.3	52.4 ± 3.5	57.6 ± 3.4
Date of dispersal	1 Aug ± 6.1	25 July ± 4.0	27 July ± 3.3
Age at final sighting (days)	86.0 ± 6.4	69.2 ± 5.7	74.4 ± 4.8
Date of final sighting	18 Aug ± 11.5	11 Aug ± 4.9	13 Aug ± 4.7
Satellite burrows used prior to final sighting[e]	5.0 ± 0.8	5.1 ± 1.7	5.1 ± 1.2
Maximum distance prior to lost contact (km)	2.7 ± 2.0	1.9 ± 1.0	2.1 ± 0.9

[a] Hatch dates calculated by subtracting each juvenile's estimated age from capture date.

[b] Number of juveniles in each family that survived to fledging age (30 days post-hatching).

[c] Distance to each juvenile's satellite burrow the day before it permanently dispersed at least 300 m from natal burrow.

[d] Dispersal defined as a permanent movement > 300 m from the natal burrow.

[e] Difference between burrows prior to final sighting and prior to dispersal is minimum number of satellite burrows used after dispersal.

Burrowing Owls), the typical juvenile gradually moved away from its natal burrow but often returned for brief periods. However, once juveniles had moved >300 m away from their natal burrow, they generally did not return to the natal area again before migrating.

STATISTICAL ANALYSES

To ensure statistical independence among observations of dispersal (Massot et al. 1994), we used data from 13 randomly selected, radio-tagged juveniles from 13 different families (1994, n = 4; 1995, n = 9). We randomly selected one of the radio-tagged birds per brood in 1994 to include in final analyses and randomly selected one bird from each of the 1995 families to radio-tag. Our small sample of owls during 1994 precludes statistical comparison of results between years. Thus, we report descriptive statistics only when considering annual variation in hatching dates, brood sizes, dispersal ages and dates, ages and dates of final sightings, rate of movements away from natal burrows, and other measurements obtained through daytime observations during the post-fledging dependency and dispersal periods of 1994 and 1995. All dates were standardized using the Julian calendar. To illustrate rate of movements away from natal burrows, we divided observations into 5-day in-

crements beginning at 26 days of age, averaged observations (up to 5) for each individual within those increments, and calculated means and standard errors of those averages across the 13 radio-tagged owls. We calculated mean angles and assessed angular dispersal data using Oriana® (version 1.0, Kovach Computing Services, Inc., Anglesey, Wales, United Kingdom). Rayleigh's test of uniformity was used to determine whether dispersal movements were significantly oriented or uniformly distributed in all directions for both years. Values are reported as means ± SE.

RESULTS

CAPTURE, BANDING, AND PRODUCTIVITY

We captured and banded 142 Burrowing Owls (12 adult males, 30 adult females, and 100 juveniles) from 43 families (n = 71, from 19 families in 1994; n = 71, from 24 families in 1995). One family nested in an artificial burrow (19-1 plastic bucket for the chamber with a 1-m long, 15-cm diameter plastic irrigation tubing for tunnel) in 1995, which we used to replace a natural burrow we were forced to excavate to determine the fate of a radio-tagged owl in 1994. All other nests were in natural burrows.
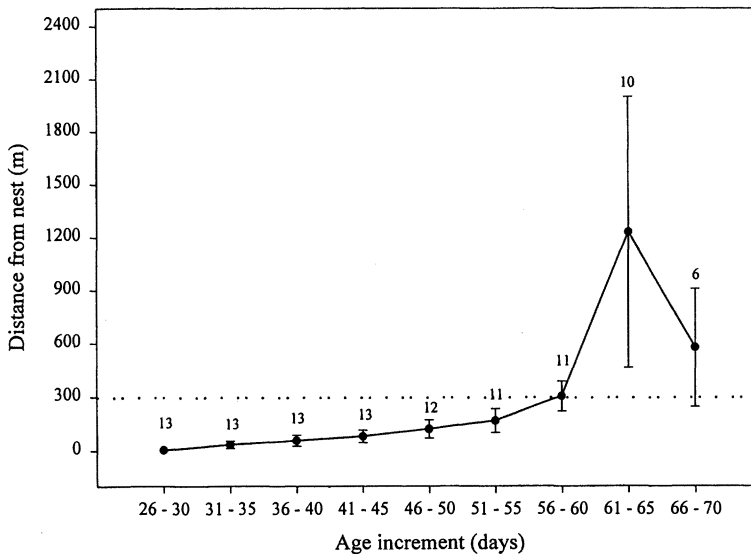
We were unable to determine clutch sizes for

FIGURE 1. Relationship between age (in 5-day increments) and distance from natal burrow for radio-tagged Burrowing Owls in southwestern Idaho during the post-fledging period in 1994 and 1995. Points (± SE) are averages of 5-day means for each individual. Number of owls contributing to plotted averages are given. Owls were considered dispersed when they permanently moved beyond 300 m (dotted line).

nests because of the subterranean nature of nest burrows. However, nests from which we radio-tagged juveniles had four to nine young reach fledging age (Table 1). Average hatch date of young that we ultimately radio-tagged and followed until migration ($n = 13$ from 13 families) was in late May (Table 1).

EARLY POST-FLEDGING PERIOD

Juveniles typically could sustain flight (the criterion we used to define fledging) at or by 30 days post-hatching, but not all of them left nest burrows at that time. Radio-tagged juveniles first left their respective natal burrows between 26 and 48 days post-hatching, at which time they moved to satellite burrows located from 18 to 230 m away (Table 1). One juvenile (26 days post-hatching) left its natal burrow before it could fly well and moved to another burrow 18 m away. After moving to satellite burrows, six (46.1%) juvenile owls returned to natal burrows (up to two times) before moving away again. This is evidenced by the fact that the average age at which we last observed young at natal burrows was approximately 4 days greater than the age at which we first observed juveniles roosting away from natal burrows (Table 1). In all, radio-tagged juveniles used an average of nearly three satellite burrows within their natal

areas for roosting before permanently dispersing.

TIMING OF DISPERSAL

The average radio-tagged Burrowing Owl dispersed in mid-summer (15 July to 22 August; median = 25 July), at which time it was between 31 and 77 days old (median = 58 days; Table 1). Because we radio-tagged more than one juvenile per family ($n = 2$ that survived to disperse from one family and $n = 3$ that survived to disperse from three other families) in 1994, we also were able to obtain an estimate of variability of dispersal ages and dates within broods for that year. Family means for dispersal age ranged from 59 ± 1.0 to 82 ± 2.9 days post-hatching ($n = 3$ for each), and dispersal dates averaged from 20–24 July ($n = 2$) in one family to 11–17 August in another. The average number of days between dispersal of the first and last radio-tagged juveniles in each family was 6 ± 1.4.

RATE OF POST-FLEDGING DISPERSAL MOVEMENTS

Figure 1 shows the relationship between age of Burrowing Owls and distance from natal burrows for 13 radio-tagged juveniles in 5-day increments beginning at day 26 and continuing un-

til 70 days of age. Beyond 70 days of age, all but a few young had presumably initiated migration, and we have not plotted data from these remaining few (averages for n = 2, 1, 2, 2, 4, and 1 owls for the 5-day increments starting with 71–75 and ending with 96–100 days of age). In general, owls exhibited gradual movements away from natal burrows (Fig. 1), although they made more abrupt and longer movements after reaching our operational cutoff of 300 m for defining dispersal from the natal area (Fig. 1). The final observations we obtained for the 13 owls before losing radio contact with them ranged from 0.5 to 9.4 km from the nest (Table 1). This occurred in mid-August when owls were an average of approximately 70 days of age (Table 1). Finally, owls associated with burrows even after dispersing beyond 300 m (Table 1).

DISPERSAL DIRECTION

Radio-tagged juveniles did not disperse in a significantly oriented direction in 1994 or 1995 (Rayleigh's test of uniformity, 1994, n = 4, r = 0.71, P = 0.14; 1995, n = 9, r = 0.26, P = 0.57). However, mean angles for each year (1994, n = 4, 137.2 ± 37.8°; 1995, n = 9, 208.9 ± 115.8°) generally were in a southerly direction from natal burrows.

SATELLITE BURROWS

Nearly and recently independent young generally associated with satellite burrows for roosting during the day within their natal area and after dispersing. Of 448 visual observations of 13 owls between 26 days of age and losing radio contact, 397 (88.6%) were at burrows (natal or satellite burrows). The remaining were in grass (n = 39), in plowed fields (n = 3), on fences (n = 6), in a recently cut hayfield (n = 3), in sagebrush (n = 1), within a roadside ditch (n = 1), and on a gravel road (n = 1), although it is possible that some of these non-burrow observations were of owls who were active rather than roosting. After leaving their respective natal burrows, the 13 radio-tagged juveniles we monitored used at least 66 different satellite burrows before we lost radio contact with them (Table 2). Although patterns varied among individuals, as juveniles aged they generally moved to satellite burrows that were farther away from their natal burrows. The first satellite burrows used were 82.0 ± 16.6 m (18–230 m; n = 13) from

TABLE 2. Distribution of 66 satellite burrows used by 13 radio-tagged juvenile Burrowing Owls within 100-m increments of their respective natal burrows in southwestern Idaho during 1994–1995. Percentages of total number of satellite burrows are provided as well as the mean number of burrows per juvenile within each distance increment.

Distance from natal burrow (m)	n	%	Mean ± SE
1–100	20	30	1.5 ± 0.4
101–200	12	18	0.9 ± 0.3
201–300	4	6	0.3 ± 0.1
301–400	3	5	0.2 ± 0.2
401–500	5	8	0.4 ± 0.2
>500	22	33	1.7 ± 1.0
All distances	66	100	5.1 ± 1.2

natal burrows, whereas the fourth and fifth burrows owls used were 219.6 ± 56.7 (70–431 m; n = 7) and 261.2 ± 45.0 m (155–350 m; n = 4) from the natal burrow, respectively. Distances between consecutively used satellite burrows (for the first five burrows used by each owl) ranged from 3–877 m and averaged between 127 ± 38.5 and 232 ± 97.6 m. Finally, juvenile Burrowing Owls roosted at a particular satellite burrow for up to 14 days. They spent 5.9 ± 1.3 days (1–14; n = 13) at the first satellite burrow they visited, and between 2.9 ± 0.6 (1–8; n = 12) and 5.4 ± 1.2 days (1–12; n = 9) at each of the next four burrows. Juveniles often moved among new and previously visited satellite burrows and seldom remained at a single satellite burrow for more than seven consecutive days.

DISCUSSION

The process whereby a recently independent migratory bird leaves its natal area and explores surrounding areas prior to its first migration is poorly understood but presumably critical to a bird's survival and future reproductive success. Ours is among the first studies to detail movements of radio-tagged Burrowing Owls during the post-fledging dispersal period and to quantify use of satellite burrows by dispersing owls. Briefly, the average juvenile spent 58 days (approximately 4 weeks after fledging) within its natal area after hatching and then dispersed (permanently moved greater than 300 m from its natal burrow) in late July. It continued to associate with satellite burrows while moving farther from

its natal area and left the study area (presumably for migration) in mid- to late-August.

TIMING AND DISTANCE OF INITIAL MOVEMENTS

On average, we first observed radio-tagged juveniles away from their respective natal burrows when about 5 weeks old, and they had permanently abandoned their natal burrows when 6 weeks old. Johnson (1997) reported that within one month of emerging, at least 20% of young, color-banded Burrowing Owls in her Davis, California population no longer associated with the nest at which they hatched, but with another nest. Although radio-tagged juveniles in our study associated with burrows away from their own nests at about the same age Johnson (1997) reports, none of these was a nest burrow of another pair. Apparently, juveniles are capable of moving between burrows when much younger than what we observed. Henny and Blus (1981) and Smith (1999) found that juveniles in artificial nest burrows began moving between burrows when as young as 10 days old. Olenick (1990) found that juveniles spent an average of 25 days in artificial nest burrows before leaving for a nearby satellite burrow. Juveniles in our study remained at natal burrows longer than those occupying artificial burrows (Henny and Blus 1981, Olenick 1990), but they did not stay as long as in Green's (1983) study in Oregon (7–8 weeks before using satellite burrows). Juveniles may depart their natal burrows earlier when subjected to repeated human disturbances (e.g., inspection of artificial nest burrows, Haug et al. 1993) or because of a higher density of satellite burrows near the nest from which to choose. Likewise, other environmental factors such as crowding and high ectoparasite loads (e.g., fleas) could affect timing of nest departure (Butts 1973).

Prior to dispersing, initial movements of juveniles were to satellite burrows between 38 and 280 m from their respective natal burrows. These distances are consistent with Martin's (1973) statement that "once juveniles could fly, they might be found at any vacant burrow within 300 m of the breeding burrow." Similarly, juveniles in California remained within 137 m of their natal burrows up to 4 weeks after emerging (i.e., when approximately 42 days old; Thomsen 1971). During this time, young still associate with adults but become increasingly independent by flying outside the natal area and foraging more for themselves.

TIMING OF DISPERSAL

Although criteria for defining dispersal varied, banded juveniles in southeastern Idaho began dispersing in July (Gleason 1978), family units in Saskatchewan began dispersing in late July and early August (Haug 1985), radio-tagged juveniles in Alberta exhibited first dispersal in mid-August (Clayton and Schmutz 1999), and juveniles in New Mexico began dispersing as early as 2 August and on through the first half of the month (Martin 1973). Radio-tagged owls in our study dispersed when an average of 58 days old, which generally occurred in late July. Frequently one or both of the parents (many of which we color-banded in this study) departed prior to each juvenile's dispersal (pers. observ.), which indicates that juveniles were independent at this time. Thus, post-fledging dispersal movements apparently occur within a window of time that coincides with mid- to late summer throughout different populations of Burrowing Owls, even at disparate latitudes.

DISTANCE AND DIRECTION OF POST-FLEDGING DISPERSAL

The average maximum distances we calculated for owls in our study before they migrated is somewhat lower than that calculated for Burrowing Owls in a radio-telemetry study in Alberta (5.5 km; Clayton and Schmutz 1999). However, at least in our study, interpretation of these values is not straightforward. Radio-tagged owls may have dispersed outside the study area before fall migration and eluded detection from ground and aerial searches despite our best efforts, in which case we would have underestimated average movement before migration. Alternatively, owls may not have dispersed as far prior to migration because (1) an adequate supply of habitat and satellite burrows were nearby in our study area, or (2) the occurrence of irrigated agriculture, which harbors abundant prey (small mammals and insects) and with which owls in southern Idaho associate (Rich 1986, Leptich 1994, Belthoff and King, unpubl. data), provided adequate resources for them to prepare physiologically for migration without moving farther.

The tendency for southward movement by juvenile Burrowing Owls in our study may cor-

respond with directional migration that follows post-fledging dispersal, but we believe it was more likely because most of the apparently suitable Burrowing Owl habitat occurred to the south, southeast, and southwest rather than north. For example, much more human development lay to the north, including the town of Kuna (3 km north of our study area), and thus did not offer the best habitat to owls. We cannot determine whether or how post-fledging dispersal movements contributed to habitat or site imprinting (Morton et al. 1991, Morton 1992), because only two juveniles for whom we confirmed breeding returned the year after we radio-tagged them. However, distances young owls moved during the post-fledging period are within the range of natal dispersal distances (based on band returns) reported for Burrowing Owls in various portions of their range (De Smet 1997, Millsap and Bear 1997, Wellicome et al. 1997). This leaves open the possibility that post-fledging dispersal movements function in habitat selection or site imprinting in Burrowing Owls as well.

SATELLITE BURROWS

Burrowing Owls use non-nest satellite burrows for shelter from the elements (heat, direct sun, wind, and precipitation), cover from predators, caching prey, and other activities. Previous investigators have mentioned juveniles or family groups using multiple burrows, but with the exception of Haug (1985), who stated that an average of four burrows were used by family groups once young began moving in the vicinity of the nesting burrow, few have quantified satellite-burrow abundance, distribution, or use throughout the post-fledging period. We consider the average number of satellite burrows used by juveniles in our study (over 5) as a minimum because juveniles certainly used additional burrows that we did not detect during field observations, which were restricted to daytime. Owls used some of these non-nest burrows for up to 14 days, which illustrates how closely they appear tied to them, even after dispersal. Clayton and Schmutz (1999) point out the somewhat paradoxical fact, which we also observed in our study of radio-tagged owls, that young owls capable of flight often do not enter the burrow at which they roost but instead, when disturbed, repeatedly fly to a nearby burrow. However, we also observed dispersing owls seek cover from

aerial predators within the burrows with which they associated. These studies clearly illustrate that dispersing Burrowing Owls require more than one satellite burrow during the post-fledging and pre-migratory period. Burrowing Owls also seem unusual among birds in their apparent need for such specific landscape features (satellite burrows) during the dispersal process. It seems logical therefore that in regions where Burrowing Owl populations are limited by burrow availability, and artificial burrows are used for management or other purposes, that sufficient numbers of artificial burrows be placed not only to meet needs of breeding adults but to benefit post-fledging and dispersing juveniles as well.

ACKNOWLEDGMENTS

LITERATURE CITED

BELTHOFF, J. R., AND A. M. DUFTY JR. 1998. Corticosterone, body condition, and locomotor activity: a model for natal dispersal in screech-owls. Anim. Behav. 54:405–415.

BUTTS, K. O. 1973. Life history and habitat requirements of Burrowing Owls in western Oklahoma. M.Sc. thesis, Oklahoma State Univ., Stillwater, OK.

CLAYTON, K. M., AND J. F. SCHMUTZ. 1999. Is the decline of Burrowing Owls *Speotyto cunicularia* in prairie Canada linked to changes in Great Plains ecosystems? Bird Conserv. Int. 9:163–185.

DE SMET, K. D. 1997. Burrowing Owl (*Speotyto cunicularia*) monitoring and management activities in Manitoba, 1987–1996, p. 123–130. *In* J. R. Duncan, D. H. Johnson, and T. H. Nichols [EDS.], Biology and conservation of owls of the Northern Hemisphere, Second International Symposium.

USDA Forest Serv. Gen. Tech. Rept. NC-GTR-190.

DUFTY, A. M., JR., AND J. R. BELTHOFF. 2000. Proximate mechanisms of dispersal: the role of hormones and body condition, p. 217–229. *In* J. Clobert, E. Danchin, A. Dhondt, and J. D. Nichols [EDS.], Dispersal. Oxford Univ. Press, London.

GLEASON, R. S. 1978. Aspects of the breeding biology of Burrowing Owls in southeastern Idaho. M.Sc. thesis, Univ. Idaho, Moscow, ID.

GREEN, G. A. 1983. Ecology of breeding Burrowing Owls in the Columbia Basin, Oregon. M.Sc. thesis, Oregon State Univ., Corvallis, OR.

HAUG, E. A. 1985. Observations on the breeding ecology of Burrowing Owls in Saskatchewan. M.Sc. thesis, Univ. Saskatchewan, Saskatoon, SK, Canada.

HAUG, E. A., B. A. MILLSAP, AND M. S. MARTELL. 1993. Burrowing Owl (*Speotyto cunicularia*). *In* A. Poole and F. Gill [EDS.], The birds of North America, No. 61. The Academy of Natural Sciences, Philadelphia and The American Ornithologists' Union, Washington, DC.

HAUG, E. A., AND L. W. OLIPHANT. 1990. Movements, activity patterns, and habitat use of Burrowing Owls in Saskatchewan. J. Wildl. Manage. 54:27–35.

HENNY, C. J., AND L. J. BLUS. 1981. Artificial burrows provide new insight into Burrowing Owl nesting biology. J. Raptor Res. 15:82–85.

JAMES, P. C., AND R. H. M. ESPIE. 1997. Current status of the Burrowing Owl in North America: an agency survey. J. Raptor Res. Report 9:3–5.

JOHNSON, B. S. 1997. Reproductive success, relatedness, and mating patterns of colonial Burrowing Owls. J. Raptor Res. Report 9:64–67.

KIRK, D. A., AND C. HYSLOP. 1998. Population status and recent trends in Canadian raptors: a review. Biol. Conserv. 83:91–118.

LANDRY, R. E. 1979. Growth and development of the Burrowing Owl *Athene cunicularia*. M.Sc. thesis, California State Univ., Long Beach, CA.

LEPTICH, D. J. 1994. Agriculture development and its influence on raptors in southern Idaho. Northwest Sci. 68:167–171.

LUTZ, R. S., AND D. L. PLUMPTON. 1999. Philopatry and nest site reuse by Burrowing Owls: implications for productivity. J. Raptor Res. 33:149–153.

MARTIN, D. J. 1973. Selected aspects of Burrowing Owl ecology and behavior. Condor 75:446–456.

MASSOT, M., J. CLOBERT, A. CHAMBON, AND Y. MICHALAKIS. 1994. Vertebrate natal dispersal: the problem of non-independence of siblings. Oikos 70:172–176.

MESSICK, J. P. 1980. Ecology of the badger in south-

western Idaho. Ph.D. diss., Univ. Idaho, Moscow, ID.

MILLSAP, B. A., AND C. BEAR. 1997. Territory fidelity, mate fidelity, and dispersal in an urban-nesting population of Florida Burrowing Owls. J. Raptor Res. Report 9:91–98.

MORTON, M. L. 1992. Effects of sex and birth date on premigration biology, migration schedules, return rates and natal dispersal in the Mountain White-crowned Sparrow. Condor 94:117–133.

MORTON, M. L., M. W. WAKAMATSU, M. E. PEREYRA, AND G. A. MORTON. 1991. Post-fledging dispersal, habitat imprinting, and philopatry in a montane, migratory sparrow. Ornis Scand. 22:98–106.

OLENICK, B. E. 1990. Breeding biology of Burrowing Owls using artificial nest burrows in southeastern Idaho. M.Sc. thesis, Idaho State Univ., Pocatello, ID.

PLUMPTON, D. L., AND R. S. LUTZ. 1993. Influence of vehicular traffic on time budgets of nesting Burrowing Owls. J. Wild. Manage. 57:612–616.

RICH, T. 1986. Habitat and nest-site selection by Burrowing Owls in the sagebrush steppe of Idaho. J. Wildl. Manage. 50:548–555.

SHEFFIELD, S. R. 1997. Current status, distribution, and conservation of the Burrowing Owl (*Speotyto cunicularia*) in midwestern and western North America, p. 399–407. *In* J. R. Duncan, D. H. Johnson, and T. H. Nichols [EDS.], Biology and conservation of owls of the Northern Hemisphere, Second International Symposium. USDA Forest Serv. Gen. Tech. Rept. NC-GTR-190.

SMITH, B. W. 1999. Nest-site selection, ectoparasites, and mitigation techniques: studies of Burrowing Owls and artificial burrow systems in southwestern Idaho. M.Sc. thesis, Boise State Univ., Boise, ID.

THOMSEN, L. 1971. Behavior and ecology of Burrowing Owls on the Oakland Municipal Airport. Condor 73:177–192.

U. S. DEPARTMENT OF THE INTERIOR. 1996. Effects of military training and fire in the Snake River Birds of Prey National Conservation Area. BLM/IDARNG Research Project Final Report. U.S. Geol. Surv., Biol. Res. Div., Snake River Field Sta., Boise, ID.

WELLICOME, T. I., G. L. HOLROYD, K. SCALISE, AND E. R. WILTSE. 1997. The effects of predator exclusion and food supplementation on Burrowing Owl (*Speotyto cunicularia*) population change in Saskatchewan, p. 487–497. *In* J. R. Duncan, D. H. Johnson, and T. H. Nichols [EDS.], Biology and conservation of owls of the Northern Hemisphere, Second International Symposium. USDA Forest Serv. Gen. Tech. Rept. NC-GTR-190.