Western Burrowing Owl
(*Athene cunicularia hypugaea*)

A Species Conservation Assessment
for
The Nebraska Natural Legacy Project

Prepared by Melissa J. Panella
Nebraska Game and Parks Commission
Wildlife Division
November 2013

The mission of the Nebraska Natural Legacy Project is to implement a blueprint for conserving Nebraska's flora, fauna, and natural habitats through the proactive, voluntary conservation actions of partners, communities, and individuals.

Purpose

The primary goal in the development of at-risk species conservation assessments is to compile biological and ecological information that may assist conservation practitioners in making decisions regarding the conservation of species of interest. The Nebraska Natural Legacy Project recognizes the western subspecies of Burrowing Owl (*Athene cunicularia hypugaea*) as a Tier I at-risk species. Provided are some general management recommendations regarding Western Burrowing Owls (hereafter Burrowing Owls). Conservation practitioners will need to use professional judgment for specific management decisions based on objectives, location, and site-specific conditions. Based on a considerable body of literature, this particular species conservation assessment provides an overview of our current knowledge of Burrowing Owls and may aid in decision-making for their conservation or in identifying research needs for the benefit of the species. Species conservation assessments will need to be updated as new scientific information becomes available. Though the Nebraska Natural Legacy Project focuses efforts in the state's Biologically Unique Landscapes (BULs), it is recommended that whenever possible, practitioners make considerations for a species throughout its range in order to increase the success of conservation efforts.

Common Name Burrowing Owl

Scientific Name *Athene cunicularia hypugaea*

Order Strigiformes

Family Strigidae

G-Rank G4 **S-Rank** S3 **Goal** 4 **Distribution** Widespread

Criteria for selection as Tier I Ranked as imperiled or vulnerable in nearly all states in its range

Trends since 2005 in NE Increasing

Range in NE Western two-thirds of state

Habitat Prairie dog towns, short-grass prairie, mixed-grass prairie, heavily grazed grasslands

Threats Prairie dog control; habitat conversion (center pivots); loss of short, open grasslands; plague in prairie dogs; industrial, utility, and wind energy development; insecticide impacts; vehicle collisions and other impacts associated with disturbance by humans

Climate Change Vulnerability Index: not vulnerable, presumed stable (NatureServe 2013)

Research/Inventory Expand surveys to assess distribution and abundance; determine productivity, cause of population variability (predators), status and trends of prairie dogs, effects of wind energy development

Landscapes Central Loess Hills, Cherry County Wetlands, Dismal River Headwaters, Elkhorn River Headwaters, Keya Paha, Kimball Grasslands, Loess Canyons, Middle Niobrara, North Platte River, Oglala Grasslands, Panhandle Prairies, Rainwater Basin, Sandhills Alkaline Lakes, Sandsage Prairie, Upper Loup Rivers and Tributaries, Upper Niobrara River, Verdigris-Bazile, Wildcat Hills, Willow Creek Prairies

Status

Burrowing Owls (*Athene cunicularia*) are listed as a Species of National Conservation Concern in several Bird Conservation Regions (BCRs), including BCR 18 (Shortgrass Prairie) that extends along the western border of Nebraska (U. S. Fish and Wildlife Service 2008). According to the last global status review in 2011, the state of Nebraska Heritage status rank of Burrowing Owls is S5, U.S. national status is N4B,N4N, and global conservation rank is G4 (NatureServe 2009). Natural Heritage conservation ranks range 1 to 5 with 1 being the most critically imperiled (for definitions of ranks, see Appendix 4 of Nebraska Natural Legacy Project; Schneider et al. 2011). Overall, populations of Burrowing Owls in the Great Plains have experienced declines (Klute et al. 2003). From 1966–2011, Burrowing Owls in Nebraska have increased slightly with a trend of 3.2, 95% CI = -0.1–6.5; however, data during the same time frame show a decline for the central mixedgrass prairie region as a whole (-4.2, 95% CI = -6.2 – -2.1) (Sauer et al. 2012). The Nebraska Natural Legacy Science Team set a goal of maintaining at least four populations in the state, assuming there is little movement between populations during the breeding season and fates of populations are not correlated (Schneider et al. 2011). Moderate viability (40% chance of survival) of each population gives >99% probability of at least one population surviving 100 years (Morris et al. 1999). However, there is recent verified documentation of a female Burrowing Owl that flew during the breeding season between two migration corridors that were largely believed to be separated, indicating that there may be more crossover between populations than previously believed and possibly greater genetic exchange (Holroyd et al. 2011). Global population size is thought to be >1,000,000 individuals (NatureServe 2011) and may be 2,000,000 with ~31% in the United States and Canada (Rich et al. 2004). Partners in Flight (2007) estimate the population of Burrowing Owls in the United States to be 700,000 with 15,000 in Nebraska.

Principal Risk Factors

Habitat Loss, Degradation, and Fragmentation

Habitat loss, degradation, and fragmentation negatively impact Burrowing Owls (Dundas and Jensen 1995). Burrowing Owls may feel pressure to abandon nests in landscapes disturbed by humans (Alberta Environment and Sustainable Resource Development 2012). Conversion of grassland to agriculture is a direct loss of habitat. Predation of Burrowing Owls increases as a result of fragmentation of grasslands (Wellicome and Haug 1995). In highly modified landscapes, unleashed pets may depredate on Burrowing Owls (Haug and Didiuk 1991).

Industry, Utility, and Wind Energy Development

Industry, utility, and wind energy developments are additional disturbances that fragment the landscape. Burrowing Owls are at risk of becoming entangled in fences and colliding with vehicles, power lines, and wind turbines (Hjertaas et al. 1995). Burrowing Owls face risks associated with the petroleum industry, including fragmentation of habitat, introduced structures for perching by predators, increased noise levels affecting the owls' abilities to hear prey, invasion of non-native plants into habitat, and possible nest abandonment (Scobie et al. 2013). Petroleum production may become more of a risk factor for Burrowing Owls given the oil boom in the Great Plains. Pollution of habitat is also possible.

Eradication of Fossorial Mammals

Fossorial mammals (e.g., burrowing mammals such as prairie dogs) are important contributors to the availability of nesting habitat for Burrowing Owls (Evans 1982). Habitat for Burrowing Owls is closely linked to black-tailed prairie dogs (*Cynomys ludovicianus*). When prairie dog eradication efforts take place, ultimately Burrowing Owls are impacted negatively.

Plague

Although Burrowing Owls do not catch plague caused by the bacterium (*Yersinia pestis*), the owls' reliance on prairie dogs for habitat means that owls can be impacted by plague epizootics (Stapp et al. 2004). Mortality of prairie dogs may lead to loss of nest sites for Burrowing Owls, a decline in owl productivity, and reduced anti-predator effects leading to increased predation of owls (Conrey 2010).

Contaminants

Burrowing Owls' exposure to contaminants applied in their environment can cause illness or mortality in the owls (Haug and Didiuk 1991). Insecticides can impact their food source (Schneider et al. 2011).

Harassment

Illegal harassment by humans (e.g., poisoning, shooting) poses yet another threat to Burrowing Owls (Hjertaas 1995). Owls may be eliminated mistakenly by those who aim to exterminate black-tailed prairie dogs. Or in some instances, Burrowing Owls have been harassed or eliminated intentionally.

Species Description

Burrowing Owls are small owls (20–25 cm long, 130–150 grams) that appear long-legged, short-tailed, have long, somewhat narrow wings, and have a slightly flattened-looking head (Sibley 2000). The eyes of a Burrowing Owl are yellow (Hjertaas 1995). The white throat and whitish 'eyebrows' are most distinctive on the adults (Sibley 2000).

FIGURE 1: An adult Western Burrowing Owl stands in the open. It is a small owl with distinctive characteristics, including seemingly long legs, short tail, yellow eyes, and white feathers on the throat and more on the face that form “eyebrows.” Photograph copyright NEBRASKAland, Nebraska Game and Parks Commission.

FIGURE 2: Burrowing Owls can be at increased risk when they are sighted in the distance and mistaken for prairie dogs that are hunted. Burrowing Owls are protected by the Migratory Bird Treaty Act – they are illegal to shoot or otherwise harm. Photograph copyright NEBRASKAland, Nebraska Game and Parks Commission.

Habitat and Range

Burrowing Owls breed in the Great Plains in open landscapes with short vegetation and little shrub cover, including native pasture and fallow fields (Dechant et al. 2003). Burrowing Owls inhabit shortgrass prairie and heavily grazed pastures, often associated closely with prairie dog towns (Faanes and Lingle 1995, Sharpe et al. 2001). Burrowing Owls use burrows created by black-tailed prairie dogs as well as those made by other burrowing mammals (e.g., American badger [*Taxidea taxus*], multiple fox species) (Sharpe et al. 2001). In eastern Colorado, Tipton and others (2007) found that occupancy of Burrowing Owls in active prairie dog colonies is much higher than in inactive colonies (0.80; 95% CI = 0.66–0.89 versus 0.23; 95% CI = 0.07–0.53). Fresh scat from prairie dogs at the burrows of Burrowing Owls suggests that the owls are capable of evicting prairie dogs from desired burrows (Plumpton and Lutz 1993) and enlarging the space as needed (Hjertaas 1995). Adult owls may select nesting burrows that are adjacent to additional burrows in higher density that the young owls will use as they grow (Plumpton and Lutz 1993). Burrowing Owls are common breeders in the western part of Nebraska, particularly in the panhandle, but uncommon in the east; they rarely occur in the state during winter, and if so, they are likely migrating rather than overwintering (Sharpe et al. 2001).

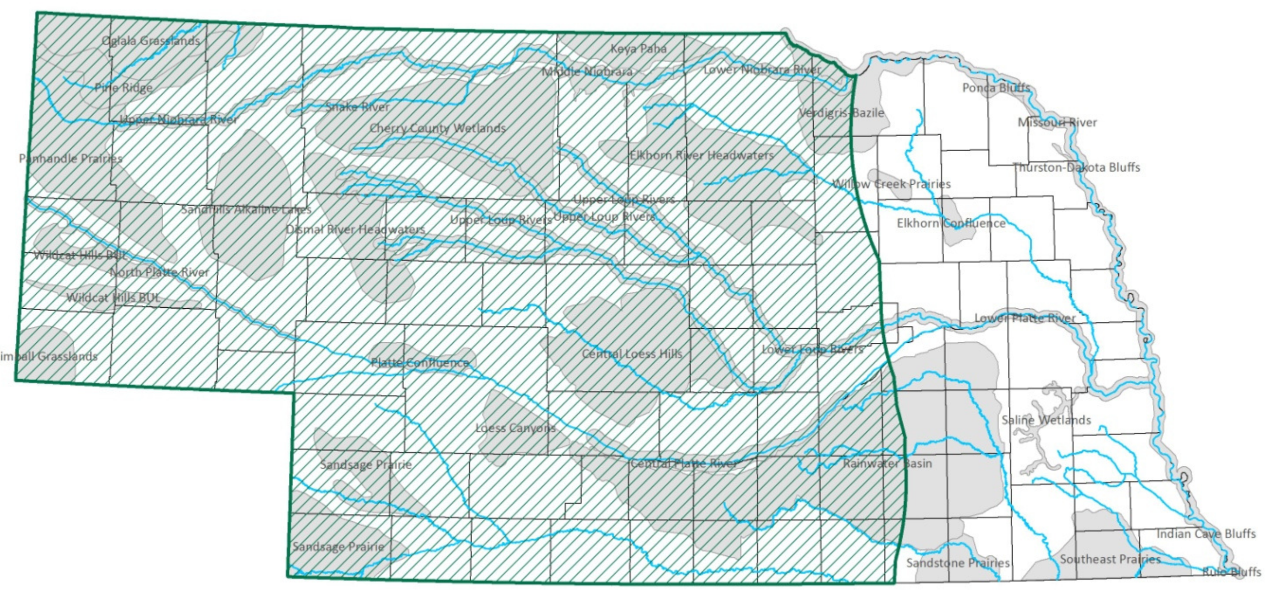

FIGURE 3. The current breeding range of Burrowing Owls in Nebraska based on field observations, museum specimens, and expert knowledge. Map courtesy of Nebraska Natural Heritage Program, Nebraska Game and Parks Commission.

Area Requirements

In Nebraska, a prairie dog town may support 1–20 Burrowing Owls (Desmond and Savidge 1996). In the panhandle of the state, Desmond (1991) estimated a mean of 0.85 pairs/ha with a range of 0.01–5.0 pairs/ha (Desmond 1991). Hughes (1993) determined density of owls was 0.02–14.50 birds/ha in Logan County, Colorado. Griebel (2000) reported pair density as 0.15–0.16/ha in South Dakota, and nest density in small colonies was 0.1–30.0 nests/ha, in large colonies was 0.03–0.4 nests/ha, and in clusters within large colonies was 0.9–2.5 nests/ha. Density in a prairie dog town in Montana was 1 pair/110 ha (Restani et al. 2001) and 0–3 pairs/100 km^2 in North Dakota (Murphy et al. 2001). In southwestern Idaho, Welty and others (2012) found nests with nearest neighbors up to 250 m away (median = 247 m, range: 84–3470 m, *n* = 47 nests). They reported average nest density index (i.e., overlap within a 200-m buffer) as 32.0% ± 3.27 (SE) (*n* = 46, range: 0–95.9%; Welty et al. 2012). In southeastern Washington, breeding densities of Burrowing Owls was 0.67 nests/km^2 at agricultural sites and 0.28 nests/km^2 in urban areas (Conway et al. 2006). Predation events on Burrowing Owls may be reduced when the owls nest in higher density (Welty 2010). Mrykalo and others (2007) found 95% kernel home range estimates of Burrowing Owl (*A. c. floridana*) juveniles to be 98–177 m^2 in Florida.

Dispersal, Migration, and Nest Site Fidelity

In Florida, one juvenile was located 10.1 km from the main and satellite burrows from which it fledged (Mrykalo et al. 2007). At the start of fall migration, juveniles in North Dakota dispersed 108 ± 21 (SE) m and 82 ± 17 (SE) m from their nest sites in 2003 and 2004, respectively (Davies and Restani 2006). Burrowing Owls captured and banded in the Great Plains have been found later in Arkansas, Oklahoma, Texas, and Mexico (Poulin et al. 2011) during winter.

Burrowing Owls exhibit breeding dispersal when their initial nests fail; this may be the case after nest loss because of predation (but clutch size decreases at site of second nest) (Catlin and Rosenberg 2008). Holroyd and others (2011) documented a female Burrowing Owl that nested in Arizona later move north 1860 km, the farthest on record for any raptor within the same breeding season, to successfully raise young in Saskatchewan. Plumpton and Lutz (1993) reported that Burrowing Owls showed strong nest site fidelity to prairie dog towns in Colorado. Sixty-six percent of returning migrants used the same colony for nesting as in the previous year and 20% (*n* = 4) of burrows were reused from 1990–1991; 90% (*n* = 18) of the prairie dog towns were re-used. In a much larger study (*n* = 555 owls banded) by the same authors, 19% of adult males, 14% of adult females, and 5% of nestlings returned to the same or adjacent 1/16 section (Lutz and Plumpton 1999).

Diet and Foraging

Burrowing Owls feed mainly on insects and small mammals (Poulin et al. 2011); they seem to prefer small mammals such as rodents over other small vertebrates and invertebrates (Silva et al. 1995). Conrey (2010) evaluated the diet of Burrowing Owls in Pawnee National Grassland, located just south of Nebraska's border with Colorado, and estimated the number of prey items consumed by Burrowing Owls was 95% insect, 4% mammal, and 1% bird; however, diet by biomass of prey items was 11% insect, 67% mammal, and 20% bird. Insects are more plentiful but selected much less frequently, because they are nutritionally less important than larger vertebrate prey (Conrey 2010). Most foraging for invertebrates takes place within 100 m of the nest burrow, but Burrowing Owls will search up to 600 m away for vertebrate prey (Haug and Oliphant 1990, Moulton et al. 2004). Foraging may sometimes occur in roadside ditches, making Burrowing Owls more vulnerable to vehicular collisions (Alberta Environment and Sustainable Resource Development 2012). Burrowing Owls may scatter dried manure near their burrows to attract insect-prey (Smith 2004). Burrowing Owls are recognized second to only Barn Owls in North America for their economic value in controlling agricultural pests such as rodents and grasshoppers (as reviewed in Fisher et al. 2007).

Reproduction

Burrowing Owls are semi-colonial nesters (Bent 1961, Poulin et al. 2011). It is likely the males are the ones that search at night (Thomsen 1971) to choose burrows formed by other animals (Poulin et al. 2011). Re-nesting may occur if first nest fails early during the breeding season (Thomsen 1971, Butts 1973, Wedgwood 1976). Characteristics of the micro-habitat appear to be very important in burrow selection, including higher density of burrows (possibly to be used as escape routes for chicks), being surrounded by bare ground or short grass ($P < 0.005$) in order to more easily spot predators (Green and Anthony 1989), sandy-loam and silty clay soils (MacCracken et al. 1985), and close proximity to roads (Plumpton and Lutz 1993). In California, nearest neighbor distances between nests range from ~120 m up to 600 m (Fisher et al. 2007). The minimum opening size of a burrow is 11–15 cm (Martin 1973, Butts and Lewis 1982, Haug 1985, MacCracken et al. 1985, Poulin et al. 2005). Burrowing Owls can perform minor excavation of a burrow but are unable to clear a burrow that has not been maintained and collapses (Gillihan and Hutchings 2013). Burrowing Owls may select nesting sites that have nearby high perches (Green 1983). Burrowing Owls have been known to nest in cavities in rock formations if burrows are not available (Gleason 1978, Gleason and Johnson 1985, Rich 1986).

Females lay and incubate 7–12 eggs for 28–30 days (as reviewed in Poulin et al. 2011; R. C. Y. Conrey, pers. comm.). Murray (1976) reported an average of 6.49 eggs/nest (n = 439 nests) with more eggs laid most likely when rich prey sources are available. The male hunts and brings the female food while she incubates (Poulin and Todd 2006). Authors report variable ages (35–53 days) for fledging based on how they choose to define the term, because young leave the hatch burrow before they are truly independent (Thomsen 1971, Landry 1979, Haug 1985, Desmond and Savidge 1999, Davies and Restani 2006, Todd et al. 2007).

Nesting success in Nebraska was reported as 3.12 fledglings/nest (n = 85) (Desmond and Savidge 1990). A later study in the state reported only 1.9 fledglings/nest (n = 398) in a colony that was subject to poisoning of prairie dogs (Desmond et al. 2000). Lantz and Conway (2009) found apparent nest survival in northeastern Wyoming to be 62.5% in 2003 and 77.8% in 2004 that was reasonably similar to values detected in several prior studies in prairie dog colonies in different states, including: 53–57% in Oregon (Green and Anthony 1989), 85% in Colorado (Plumpton 1992), and 76% in South Dakota (Griebel and Savidge 2007). Barclay and others (2011) found that nesting success in artificial burrows was similar to that of natural burrows. Average fecundity was 3.36 juveniles/pair (SD = 0.98) in artificial burrows (Barclay et al. 2011). Number of young that fledged per successful nest ranged from 2.9–7.8 (summaries in Poulin et al. 2011). Daily nest survival was higher in burrows with a longer tunnel length (Lantz and Conway 2009).

Survival

The most significant causes of adult mortality reported in Canada are predation (especially by raptors and American badgers), starvation, disease, and collisions with vehicles (Alberta Sustainable Resource Development and Alberta Conservation Association 2005, Environment Canada 2010). Barclay and others (2011) analyzed population dynamics of a colony of Burrowing Owls in San Jose, California whose burrows were managed. They found annual adult survival to be 0.71 during a 6-year period of population increase and to be 0.47 during a subsequent 6-year period of decrease. Annual survival of juveniles did not differ between the two time frames. They estimated long term population growth to be 1.07 over the span of 12 years (Barclay et al. 2011). Several studies estimate the annual survival of juvenile Burrowing Owls to be ~20–30% (James et al. 1997, Johnson 1997, Millsap 2002, Rosenberg and Haley 2004). Davies and Restani (2006) estimated survival of juveniles during the post-fledging period to be 0.57 (95% CI: 0.41–0.73). Davies and Restani (2006) report >66% of first-year mortality in North Dakota takes place during the post-fledging period because of starvation or predation. In Canada, mortality in the post-fledging period is most likely to be caused by predation (Shyry and Todd 2000, Todd 2001), followed by risk of death from collisions with vehicles or fences (Shyry and Todd 2000). The lifespan of a wild Burrowing Owl is ~8 years (Kennard 1975).

Research and Conservation Strategies

A multitude of factors should be considered before implementing any conservation actions. Within the guidelines of state and federal law, the Nebraska Natural Legacy Project recommends: 1) consider, but do not limit options to, scenarios that benefit not only the species of interest but also property owners, 2) consider species dispersal and landscape context, 3) plan for multiple years, and 4) do no harm.

In Nebraska, there are many BULs where one can make conservation considerations for Burrowing Owls: Central Loess Hills, Cherry County Wetlands, Dismal River Headwaters, Elkhorn River Headwaters, Keya Paha, Kimball Grasslands, Loess Canyons, Middle Niobrara, North Platte River, Oglala Grasslands, Panhandle Prairies, Rainwater Basin, Sandhills Alkaline Lakes, Sandsage Prairie, Upper Loup Rivers and Tributaries, Upper Niobrara River, Verdigris-Bazile, Wildcat Hills, and Willow Creek Prairies. The Nebraska Natural Legacy project identified these landscapes as places that offer the best opportunities for conservation of Burrowing Owls in the state based on current knowledge. Given the principal threats identified, research and conservation efforts for Burrowing Owls (summarized in Table 1) may want to employ the following strategies:

1. Develop a better understanding of their distribution and trends through surveys. To minimize disturbance to owls, conduct roadside surveys, using a single vehicle with 1–2 observers (Conway and Simon 2003, Manning and Kaler 2011). Surveys on foot are possible, but the owls may respond sooner to human presence by hiding (R. C. Y. Conrey, pers. comm.). For large-scale monitoring efforts, a driving survey is more practical and effective, but detection probability can be higher using point-counts (Conway and Simon 2003). A maximum distance of 125–150 m is recommended for positive identification of owls (Conway and Simon 2003, Tipton et al. 2008), but with the aid of quality optics this distance may be greater (R. C. Y. Conrey, pers. comm.). Do not assume Burrowing Owls only use burrows during the breeding season. They may be found in burrows during spring (beginning in January or February) and fall

(into November) migration in Nebraska (Sharpe et al. 2001), although most will be gone during these times. When surveying in agro-ecosystems, keep in mind that burrows near irrigated cropland may be preferred because of increased prey availability (Moulton et al. 2006). In southern California, LaFever and others (2008) observed Burrowing Owls, particularly females, which used burrows outside the breeding season during early afternoon. Manning and Garton (2012) had success sighting Burrowing Owls during afternoon hours. Conway and Simon (2003) conducted driving surveys from 0600–2000 MDT. Burrowing Owls could be more challenging to detect when they go underground to keep cool during the heat of the day (R. C. Y. Conrey, pers. comm.), and morning surveys may be preferred for the point-count method (in conjunction with call-broadcasts because the owls tend to vocalize less as the day progresses; Conway and Simon 2003). Manning (2011) suggests that surveys be planned to avoid times when temperatures are >33°C and winds are high. When surveyors are trying to document reproduction, it is best to conduct surveys from mid- to late-June and July to find owlets, because females are mostly below ground during incubation and nestling periods (R. C. Y. Conrey, pers. comm.).

2. Playbacks of recorded calls are sometimes used to find bird species that are responsive to the recordings and otherwise challenging to locate. Thiele (2012) had success using call-broadcasts of Burrowing Owls a half-hour before sunrise to a half-hour after sunset to detect Burrowing Owls in grasslands of western South Dakota. Thiele's playbacks consisted of 30 secs of the male owl's primary "coo-coo" call, 30 secs of silence, another 30 secs of the primary male call, another 30 secs of silence, 30 secs of alarm calls, and another 30 secs of silence. Conway and Simon (2003) used call-broadcasts from 0600–1115 MDT in eastern Wyoming; Burrowing Owls did not always respond vocally, but the authors report that their call-broadcasts elicited change in owl behavior that aided in detection. They suggest that this method is most effective early in the breeding season when nests are being established and egg-laying commences (Conway and Simon 2003). During the breeding season of Burrowing Owls in the Tropics, Braga and Motta-Junior (2009) found that playback surveys for the owls on nights when the moon was full or near-full yielded better results. As may be expected, Burrowing Owls call less and are less detectable during periods of high winds in open grassland habitat (Braga and Motta-Junior 2009). It is uncertain whether or not detectability patterns would be influenced by lunar phase in a temperate region (Pardeick et al. 1996), but it may be worthwhile to consider phase of the moon (in addition to wind velocity) when planning to conduct surveys using recorded playback calls.

3. Before employing conservation actions, researchers may want to track Burrowing Owls to answer questions regarding their home range, movement patterns, and survivorship. Chipman and others (2007) looked at the effects of radio-transmitters on Burrowing Owls. They found that although the owls spent significantly more time interacting with their necklace-style tracking devices, rather than being vigilant or resting, than owls without devices, their survivorship and fitness were not impacted (Chipman et al. 2007). However, Gervais and others (2006a) found that necklace-style radio-collars can affect survival of Burrowing Owls, particularly males. Necklace-style radio-transmitters used in both studies referenced here were Model PD-2C, Holohil Systems Ltd., Ontario, Canada. Gervais and others (2006a) recommend avoiding use of the harness style radio-transmitters completely.

4. Once nesting Burrowing Owls are located, monitoring can be conducted to determine their productivity. In a successful nest, observers can find owlets emerging from burrows 10–14 days after they hatch (R. C. Y. Conrey, pers. comm.). In eastern Washington, Garcia and Conway (2009) used video probes in burrows to monitor nest productivity, without affecting reproduction or recruitment of owls. Video probes could be used to document the egg and nestling stages if desired.

5. Increased abundance of prey may enhance success of Burrowing Owls; in Saskatchewan, nests that were supplemented with food fledged almost twice as many owlets (Wellicome 2000). Enhance prey habitats by planting strips of native vegetation (Wellicome et al 1997a) and maintaining hay fields and uncultivated areas with tall vegetation within 1 km (~0.6 mi) of Burrowing Owls' nests (Haug 1985, Haug and Oliphant 1990, Pezzolesi 1994, Wellicome 1994, 1997a, Warnock 1997). Burrowing Owls southwest of Fresno, California demonstrated population fluctuations positively correlated to changes in numbers of a primary food source, voles (Gervais et al. 2006b). The Burrowing Owls' pellets can be examined to document their diets, including the small mammals they consume (Smith 1993, Torres et al. 2004).

6. Maintain contiguous areas of native grassland (as reviewed in Dechant et al. 2003) and short-stature vegetation. Short vegetation is important to the ability of Burrowing Owls to detect both prey and predators (Thiele 2012). Lands managed every 2–3 years with fire may provide more suitable conditions for Burrowing Owls than lands where fire is suppressed. Burned areas may have shorter stature vegetation more conducive to the owls' foraging techniques (Tubelis and Delitti 2010). In the Cerrado of South America, Tubelis and Delitti (2010) found higher densities of breeding Burrowing Owls in firebreaks and managed grasslands than in unmanaged grasslands. While planning prescribed burns, consider potential fire impacts to other species of wildlife. Some species will benefit while others will not or could even be affected negatively. Rotational grazing strategies or mowing in early spring when birds are returning from their wintering areas in search of nest sites can reduce vegetation height. Additional mowing can be delayed until late July after most juveniles have fledged (as reviewed in Drilling et al. 2011). The maintenance of colonies of black-tailed prairie dogs will also aid in promoting short–stature vegetation characteristic of a high-quality prairie.

7. Abiotic characteristics are likely important for Burrowing Owls. Soil and climate variables may best predict habitat suitability for Burrowing Owls over many biotic variables; see Stevens et al. (2011) for details about predictive modeling. Weather events (e.g., heavy rains) can reduce productivity of Burrowing Owls (Lehman et al. 1999).

8. Situations may arise that justify the relocation of nests of Burrowing Owls to prevent their demise. Relocations of nests over relatively short distances (~100 m or less) are more likely to succeed than those relocated longer distances (~180 m or more) (Smith and Belthoff 2001b). Relocation may be passive (i.e., exclusion during non-breeding season) or active (i.e., capture and move) (Smith and Belthoff 2001b). Capture should be avoided for nests in the egg or early nestling stage, because the adults will likely abandon the nest (R. C. Y. Conrey, pers. commm.). The placement of artificial burrows of the appropriate nest dimensions (10 cm diameter tunnels and >900 cm^2 chambers) (Smith and Belthoff 2001a) and proximity (Smith and Belthoff 2001b) can alleviate conflicts during construction projects that would otherwise lead to nest failures and mortality of Burrowing Owls (Catlin and Rosenberg 2006). In Idaho, Belthoff and Smith (2003) witnessed 55.4% ± 4.3 (SE) annual occupancy of artificial 2–3 burrows/cluster

over a 5-year period. Thirty-two and a half percent of these clusters were reoccupied each year for ≥4 years (Belthoff and Smith 2003). Productivity in artificial burrows appears to be similar to that in natural burrows (Botelho and Arrowood 1998, Smith and Belthoff 2001a).

9. Carefully evaluate whether Burrowing Owls are present before construction-related, ground-disturbing activities occur in areas likely to be used by Burrowing Owls during the breeding season and migration. Adhere to guidelines regarding setback distances and timing restrictions for industrial activities such as petroleum development. A distance that not only is likely to prevent flushing of Burrowing Owls, but also avoids stressing them, is recommended (Vos et al. 1985, Rodgers and Smith 1995, Environment Canada 2009). If the level of disturbance is low, 50-m setback may be acceptable outside the breeding season from 16 October to 31 March; if level of disturbance is moderate to high during the breeding season, 100–500-m setback may be needed (see Environment Canada 2009 recommendations). The California Burrowing Owl Consortium (1997) recommends at least a 100-m foraging radius from burrows remains undisturbed. Additionally, post speed limits (50 kph [~30 mph]; Environment Canada 2009) to reduce owl vehicular collisions and avoid industrial work during peak hours for the owls to forage (i.e., 2 hrs after sunset and again 2 hrs before sunrise) (Scobie et al. 2013).

10. Considerations for Burrowing Owls should be made when siting wind turbines and associated infrastructure. Burrowing Owls are vulnerable to direct [and possibly indirect] mortality from wind turbines (Smallwood et al. 2007). Smallwood and others (2007) found that dung accumulation (see item number 11 for explanation) within 20 m of burrows increased the likelihood of Burrowing Owls flying into rotor zones and colliding with blades. Intermittent rodent control near turbines (e.g., of ground squirrels) may exacerbate the problem as populations of Burrowing Owls fluctuate in response to the control measures (Smallwood et al. 2007). When grazing occurs near wind turbines, prevent dung accumulation and discourage intermittent rodent control in areas of close proximity to wind power sources.

11. Some authors have suggested that the placement of dried manure from large mammals in habitats used by Burrowing Owls may contribute to important functions for the owls (Green and Anthony 1997, Dechant et al 2003, Colorado Division of Wildlife 2003). Burrowing Owls have been observed using the manure, possibly to attract prey and to deter predators from finding young.

12. Pesticides have known direct toxicity to Burrowing Owls and can decrease their invertebrate food supply (Dechant et al. 2003, Klute et al. 2003). Rodenticides limit the number of burrowing mammals and the availability of nesting burrows suitable to Burrowing Owls (Ratcliff 1986, James and Fox 1987, James et al. 1990, Baril 1993, Berkey et al. 1993, Pest Management Regulatory Agency 1995, Hjertaas 1997, Wellicome 1997b). Authors suggest that agricultural pesticides affect reproduction by altering the amount of hormones adult female birds deposit into their eggs (Verboven et al. 2008, Poisbleau et al. 2009). Discourage overuse of chemicals (e.g., anti-cholinesterase insecticides, carbaryl, carbofuran, and rodenticides) and choose lowest toxicity levels to achieve desired results in agro-ecosystems (Drilling et al. 2011), particularly at distances <400–600 m from nest burrows (James and Fox 1987, Haug and Oliphant 1990, Dechant et al. 2003). Burrowing Owls and other wildlife are vulnerable to strychnine, which has been used for lethal control of ground squirrels (Alberta Environment and Sustainable Resource Development 2012). In the United States, the use of strychnine above-ground is illegal (Environmental Protection Agency 1996). If land managers still feel that

application of chemicals is necessary, try to delay use until a couple of months (~Aug–Sept) after most of the young have left the nest in mid-July (Drilling et al. 2011).

13. When possible, make efforts to conserve small burrowing mammals. Burrowing Owls are most successful on active prairie dog colonies (Desmond et al. 2000, Sidle et al. 2001). When prairie dogs are eliminated from the landscape because of disease or eradication by humans, vegetation becomes denser and burrows become inhospitable to Burrowing Owls within 1–3 years (Grant 1965, Butts 1973). Prairie dogs help maintain structural integrity of the burrows that the owls use (MacCracken et al. 1985, Desmond 1991, Desmond and Savidge 1999). Management plans that maintain healthy prairie dogs in the landscape benefit Burrowing Owls, as well as a suite of species associated with shortgrass prairies (Tipton et al. 2007). At minimum, control efforts directed at prairie dogs should be limited to periods when Burrowing Owls are not establishing nesting sites or maintaining active nests (Butts 1973). Education efforts can promote habitat for Burrowing Owls and possibly improve perceptions regarding prairie dogs.

14. Greater human awareness of Burrowing Owls may aid in their conservation. Environmental education and outreach efforts (e.g., meetings, presentations, brochures, website materials) geared toward landowners, land managers, and the public may increase acceptance of the needs of Burrowing Owls and the species that they rely on for maintenance of suitable habitat. Conservation of habitat for Burrowing Owls is extremely challenging without changes to current policy regarding prairie dog control. Additionally, training individuals how to identify Burrowing Owls from a distance could decrease accidental shootings that result from hunters mistakenly identifying the owls as prairie dogs.

15. Organize and conduct stewardship programs that explain how Burrowing Owls can be conserved without negatively affecting the livelihoods of private landowners and managers. Offer financial incentives to producers and landowners who actively conserve habitat for Burrowing Owls and small burrowing mammals (Drilling et al. 2011).

Information Gaps

Survey efforts in Nebraska could be expanded to assess and monitor the distribution and abundance of Burrowing Owls. Productivity estimates could be developed. Potential research topics include the link of predation to local population variability, the status and trends of prairie dogs, and effects of oil and gas and wind energy development on Burrowing Owls and their habitat.

Considerations for Additional Species

At-risk species, including keystone and indicator species, which share habitat with Burrowing Owls should be considered in management plans. On-the-ground conservation for Burrowing Owls may affect or be influenced by species that can be found in the same BULs. Associated species that may also benefit from conservation of Burrowing Owls are listed below.

<u>Animals</u>

American Badger (*Taxidea taxus*)
Black-tailed Prairie Dog (*Cynomys ludovicianus*)
Coyote (*Canis latrans*)
Ferruginous Hawk (*Buteo regalis*)
Golden Eagle (*Aquila chrysaetos*)
Gray Fox (*Urocyon cinereoargenteus*)
Red Fox (*Vulpes vulpes*)
Swift Fox (*Vulpes velox*)
Striped Skunk (*Mephitis mephitis*)
Woodchuck (*Marmota monax*)
Mountain Plover (*Charadrius montanus*)

<u>Plants</u>

Antelope bitterbrush (*Purshia tridentata*)
Sagebrush (*Artemisia* spp.)
Stiffstem flax (*Linum rigidum*)

TABLE 1. Summary of suggested management for Burrowing Owls (BUOW) in Nebraska. The following are general guidelines based on the best available knowledge at the time of this publication. See Research and Conservation section of this document for more detail and Literature Cited section for sources of additional information.

FOCUS	**STRATEGIES**	**MITIGATION and CONSIDERATIONS**
Locate BUOW and monitor nests	Search in and near prairie dog colonies and other suitable environments. Survey with a single vehicle with 1–2 observers to minimize disturbance to the owls. Use tracking methods and recorded calls as needed.	BUOW are increasingly reliant on agro-ecosystems, likely because of conversion of prairie to agricultural uses
Maintain native grassland and short-stature vegetation	Use prescribed fire before birds are nesting and/or mow/graze in mid-March. Maintain a healthy population of black-tailed prairie dogs on the landscape.	BUOW are better able to hunt prey and see and escape predators in short grasslands and on bare ground
Maintain suitable habitat for a suite of shortgrass prairie species	Create heterogeneity in the landscape with diverse native prairie species	Policies that involve eradication of prairie dogs eliminate habitat for BUOW and other species, as well as disrupt the ecosystem

TABLE 1 (Cont.)

FOCUS	STRATEGIES	MITIGATION and CONSIDERATIONS
Ensure suitable habitat for prey of BUOW	Allow for hayfields and patches of native tall vegetation. Avoid overuse of pesticides.	Castings are an excellent way to determine diets of BUOW
Maintain sustainable populations of burrowing mammals	Education and outreach efforts to develop an understanding and appreciation of the importance of keystone species to the ecology of the Great Plains	Current policy in Nebraska that establishes control measures against prairie dogs is based more on myth and long-standing practice than on scientific literature recognizing the importance of this keystone species to other wildlife, vegetation structure, productivity, nutrient cycling, and ecosystem processes (McCain et al. 2013)
Reduce loss of BUOW as a result of construction projects and petroleum development	Establish setbacks for construction/industry from burrows. At sites of planned industrial activities, deter nesting before the breeding season begins and construct artificial burrows elsewhere in clusters of 2–3 if encouraging owls to relocate to a new location.	Burrows with a 10 cm diameter opening and a chamber of >900 cm^2 are best protected from larger predators, reduce crowding within the nest, and offer a more favorable microclimate. Smith and Belthoff (2001a) give recommendations for artificial burrow design.
Properly site wind turbines to minimize impacts to wildlife	Stay engaged with wind energy developers and conduct pre- and post-construction monitoring	Intermittent rodent control measures near wind turbines may increase the likelihood of negative impacts to BUOW
Use predictive modeling of habitat for BUOW	Evaluate black-tailed prairie dog presence, vegetation characteristics (e.g., height, bare ground), and soil and climate variables around actual and potential nest sites	Soil and climate may be more influential on habitat suitability than some biotic factors
Develop innovative conservation solutions and possible financial incentives to landowners who manage their properties to avoid harm to BUOW and improve habitat.	Offer monetary incentives to producers at rates to offset effects that may occur in some systems (e.g., at 20% prairie dog occupancy on pasture, steer weight gain declined ~5% in Colorado; Derner et al. 2006).	Herbivory by black-tailed prairie dogs may actually improve forage quality and nutrient cycling. But at a certain carrying capacity of grasslands for large grazers, prairie dogs can have an impact on amount of forage (Whicker and Detling 1988).

Acknowledgments

Reesa Conrey of Colorado Department of Natural Resources provided valuable comments that greatly improved an earlier version of this document, and she provided direction to additional sources of information. Ross Lock, Nancy Drilling, and Angela Dwyer of Rocky Mountain Bird Observatory were gracious in agreeing to provide a review and offered helpful suggestions. Sara Peterson of the Nebraska Game and Parks Commission assisted in finding literature relevant to this assessment.

Literature Cited

ALBERTA ENVIRONMENT AND SUSTAINABLE RESOURCE DEVELOPMENT. 2012. Alberta Burrowing Owl recovery plan 2012–2017. Alberta recovery plan. Number 21. Alberta Environment and Sustainable Resource Development, Edmonton, Alberta, Canada.

ALBERTA SUSTAINABLE RESOURCE DEVELOPMENT AND ALBERTA CONSERVATION ASSOCIATION. 2005. Status of the Burrowing Owl (*Athene cunicularia*) in Alberta: update 2005. Wildlife Status Report Number 11. Alberta Sustainable Resource Development, Edmonton, Alberta, Canada.

BARCLAY, J. H., N. M. KORFANTA, AND M. J. KAUFFMAN. 2011. Long-term population dynamics of a managed Burrowing Owl colony. Journal of Wildlife Management 75:1295–1306.

BARIL, A. 1983. Pesticides and wildlife in the prairies: current regulatory issues. Pages 44–48 *in* Proceedings of the third endangered species and prairie conservation workshop. Natural History Occasional Paper 19 (G. L. Holroyd, H. L. Dickson, M. Regnier, and H. C. Smith, Editors). Provincial Museum of Alberta, Edmonton, Canada.

BELTHOFF, J. R. AND B. W. SMITH. 2003. Patterns of artificial burrow occupancy and reuse by Burrowing Owls in Idaho. Wildlife Society Bulletin 31:138–144.

BENT, A. C. 1961. Life histories of North American birds of prey, part 2. Dover Publications, Inc., New York, New York, USA.

BERKEY, G., R. CRAWFORD, S. GALIPEAU, D. JOHNSON, D. LAMBETH, AND R. KREIL. 1993. A review of wildlife management practices in North Dakota: effects on nongame bird populations and habitats. Report submitted to Region 6. U. S. Fish and Wildlife Service, Denver, Colorado, USA. www.npwrc.usgs.gov/resource/wildlife/wildmgmt/ (accessed 2 Jul 2013).

BOTELHO, E. S. AND P. C. ARROWOOD . 1998. The effect of burrow site use on the reproductive success of a partially migratory population of western Burrowing Owls (*Speotyto cunicularia hypugaea*). Journal of Raptor Research 32:233–240.

BUTTS, K. O. 1973. Life history and habitat requirements of Burrowing Owls in western Oklahoma. Thesis. Oklahoma State Univ., Stillwater, USA.

BUTTS, K. O. AND J. C. LEWIS. 1982. The importance of prairie dog towns to Burrowing Owls in Oklahoma. Proceedings of the Oklahoma Academy of Science 62:46–52.

CALIFORNIA BURROWING OWL CONSORTIUM. 1997. Burrowing Owl survey protocol and mitigation guidelines. Journal of Raptor Research 9:171–177.

CATLIN, D. H. AND D. K. ROSENBERG. 2006. Nest destruction associated with mortality and dispersal of Burrowing Owls in the Imperial Valley, California. Southwestern Naturalist 51:406–409.

CATLIN, D. H. AND D. K. ROSENBERG. 2008. Breeding dispersal and nesting behavior of Burrowing Owls following experimental nest predation. American Midland Naturalist 159:1–7.

CHIPMAN, E. D., N. E. MCINTYRE, J. D. RAY, M. C. WALLACE, AND C. W. BOAL. 2007. Effects of radiotransmitter necklaces on behaviors of adult male western Burrowing Owls. Journal of Wildlife Management 71:1662–1668.

CONREY, R. C. Y. 2010. Breeding success, prey use, and mark-resight estimation of Burrowing Owls nesting on black-tailed prairie dog towns: plague affects a non-susceptible raptor. Dissertation. Colorado State University, Fort Collins, USA.

CONWAY, C. J., V. GARCIA, M. D. SMITH, L. A. ELLIS, AND J. L. WHITNEY. 2006. Comparative demography of Burrowing Owls in agricultural and urban landscapes in southeastern Washington. Journal of Field Ornithology 77:280–290.

CONWAY, C. J. AND J. C. SIMON. 2003. Comparison of detection probability associated with Burrowing Owl survey methods. Journal of Wildlife Management 67:501–511.

DAVIES, J. M. AND M. RESTANI. 2006. Survival and movements of juvenile Burrowing Owls during the postfledging period. Condor 108:282–291.

DECHANT, J. A., M. L. SONDREAL, D. H. JOHNSON, L. D. IGL, C. M. GOLDADE, P. A. RABIE, AND B. R. EULISS. 2003. Effects of management practices on grassland birds: Burrowing Owl. Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA.

DERNER, J. D., J. K. DETLING, AND M. F. ANTOLIN. 2006. Are livestock weight gains affected by black-tailed prairie dogs? Frontiers in Ecology and the Environment. 4:459–464.

DESMOND, M. J. 1991. Ecological aspects of Burrowing Owl nesting strategies in the Nebraska panhandle. Thesis. University of Nebraska, Lincoln, USA.

DESMOND, M. J. AND J. A. SAVIDGE. 1990. Solitary vs. gregarious nesting in Burrowing Owls. Nebraska Bird Review 58:77.

DESMOND, M. J. AND J. A. SAVIDGE. 1996. Factors influencing Burrowing Owl (*Speotyto cunicularia*) nest densities and numbers in western Nebraska. American Midland Naturalist 136:143–148.

DESMOND, M. J. AND J. A. SAVIDGE. 1999. Satellite burrow use by Burrowing Owl chicks and its influence on nest fate *in* Ecology and conservation of grassland birds in the western hemisphere (P. D. Vickery and J. R. Herkert, Editors). Studies in Avian Biology 19.

DESMOND, M. J., J. A. SAVIDGE, AND K. M. ESKRIDGE. 2000. Correlations between Burrowing Owl and black-tailed prairie dog declines: a 7-year analysis. Journal of Wildlife Management 64:1067–1075.

DRILLING, N., L. SNYDER, AND B. BLY. 2011. Best management practices for Burrowing Owl conservation. Rocky Mountain Bird Observatory, Brighton, Colorado, USA.

DUNDAS, H. AND J. JENSEN. 1994/95. Burrowing Owl status and conservation. Bird Trends. Canadian Wildlife Service:21–22.

ENVIRONMENT CANADA. 2009. Petroleum industry activity guidelines for wildlife species at risk in the prairie and northern region. Canadian Wildlife Service, Environment Canada, Prairie and Northern Region, Edmonton, Alberta, Canada

ENVIRONMENT CANADA. 2010. Recovery strategy for the Burrowing Owl (*Athene cunicularia*) in Canada (revised version). Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa, Ontario, Canada.

EVANS, D. L. 1982. Status reports on twelve raptors. U.S. Department of the Interior, Fish and Wildlife Service, Special Scientific Report Number 238.

FAANES, C. A. AND G. R. LINGLE. 1995. Breeding birds of the Platte River Valley of Nebraska. Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA. www.npwrc.usgs.gov/resource/birds/platte/ (accessed 2 Jul 2013).

FISHER, J. B., L. A. TRULIO, G. S. BIGING, AND D. CHROMCZAK. 2007. An analysis of spatial clustering and implications for wildlife management: a Burrowing Owl example. Environmental Management 39:403–411.

GARCIA, V. AND C. J. CONWAY. 2009. Use of video probe does not affect Burrowing Owl reproductive parameters or return rates. 73:154–157.

GERVAIS, J. A., D. H. CATLIN, N. D. CHELGREN, AND D. K. ROSENBERG. 2006a. Radiotransmitter mount type affects Burrowing Owl survival. Journal of Wildlife Management 70:872–876.

GERVAIS, J. A., C. M. HUNTER, AND R. G. ANTHONY. 2006b. Interactive effects of prey and p,p'-DDE on Burrowing Owl population dynamics. Ecological Applications 16:666–677.

GILLIHAN, S. W. AND S. W. HUTCHINGS. 2013. Best management practices for shortgrass prairie birds: a landowners's guide. Colorado Bird Observatoty, Brighton, Colorado, USA. www.rmbo.org/pubs/downloads/bmp.pdf (accessed 4 Oct 2013).

GLEASON, R. S. 1978. Aspects of the breeding biology of Burrowing Owls in southeastern Idaho. Thesis. University of Idaho, Moscow, USA.

GLEASON, R. S. AND D. R. JOHNSON. 1985. Factors influencing nesting success of Burrowing Owls in southeastern Idaho. Great Basin Naturalist 45:81–84.

GRANT, R. A. 1965. The Burrowing Owl in Minnesota. Loon 37:2–17.

GREEN, G. A. 1983. Ecology of breeding Burrowing Owls in the Columbia basin, Oregon. Thesis. Oregon State University, Corvallis, USA.

GREEN, G. A. AND R. G. ANTHONY. 1989. Nesting success and habitat relationships of Burrowing Owls in the Columbia Basin, Oregon. Condor 91:347–354.

GREEN, G. A. AND R. G. ANTHONY. 1997. Ecological considerations for Burrowing Owls. Pages 117–121 *in* The Burrowing Owl, its biology and management: including proceedings of 1st international symposium on Burrowing Owls. Journal of Raptor Research Report # 9 (J. L. Lincer and K. Steenhof, Editors).

GRIEBEL, R. 2000. Ecological and physiological factors affecting nesting success of Burrowing Owls in Buffalo Gap National Grassland. Thesis. University of Nebraska, Lincoln, USA.

GRIEBEL, R. L. AND J. A. SAVIDGE. 2007. Factors influencing Burrowing Owl reproductive performance in unfragmented shortgrass prairie. Journal of Raptor Research 41:212–221.

HAUG, E. A. 1985. Observations on the breeding ecology of Burrowing Owls in Saskatchewan. Thesis. University of Saskatchewan, Saskatoon, Canada.

HAUG, E. A. AND A. B. DIDIUK. 1991. Updated status report on the Burrowing Owl *Athene cunicularia hypugaea* in Canada. Committee on the Status of Endangered Wildlife in Canada (COSEWIC), Gatineau, Canada.

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

HJERTASS, D. G. 1995. National recovery plan for the Burrowing Owl. Executive summary. Report Number 13. Recovery of Nationally Endangered Wildlife Committee, Canadian Wildlife Service, Ottawa, Canada.

HJERTASS, D. G. 1997. Recovery plan for the Burrowing Owl in Canada. Pages 107–111 *in* The Burrowing owl, its biology and management: including the Proceedings of the First International Symposium (J. L. Lincer and K. Steenhof, Editors). Raptor Research Report Number 9.

HOLROYD, G. L., C. J. CONWAY, AND H. E. TREFRY. 2011. Breeding dispersal of a Burrowing Owl from Arizona to Saskatchewan. Wilson Journal of Ornithology 123:378–381.

HUGHES, A. J. 1993. Breeding density and habitat preference of the Burrowing Owl in northeastern Colorado. Thesis. Colorado State University, Fort Collins, USA.

JAMES, P. C., T. J. ETHIER, AND M. K. TOUTLOFF. 1997. Parameters of a declining Burrowing Owl population in Saskatchewan. Pages 34–37 *in* The Burrowing Owl: its biology and management, including the proceedings of the first international symposium. (J. L. Lincer and K. Steenhof, Editors). The Raptor Research Foundation, Inc., Boise, USA.

JAMES, P. C. AND G. A. FOX. 1987. Effects of some insecticides on productivity of Burrowing Owls. Blue Jay 45:65–71.

JAMES, P. C., G. A. FOX, AND T. J. ETHIER. 1990. Is the operational use of strychnine to control ground squirrels detrimental to Burrowing Owls? Journal of Raptor Research 24:120–123.

JOHNSON, B. S. 1997. Demography and population dynamics of the Burrowing Owl. Pages 28–33 *in* The Burrowing Owl: its biology and management, including the proceedings of the first international symposium. (J. L. Lincer and K. Steenhof, Editors). The Raptor Research Foundation, Inc., Boise, USA.

KENNARD, J. H. 1975. Longevity records of North American birds. Bird-Banding 46:55–73.

KLUTE, D. S., L. W. AYERS, M. T. GREEN, W. H. HOWE, S. L. JONES, J. A. SHAFFER, S. R. SHEFFIELD, AND T. S. ZIMMERMAN. 2003. Status assessment and conservation plan for the Western Burrowing Owl in the United States. U.S. Department of the Interior, U. S. Fish and Wildlife Service, Washington, D. C., USA.

LAFEVER, D. H., K. E. LAFEVER, D. H. CATLIN, AND D. K. ROSENBERG. 2008. Diurnal time budget of Burrowing Owls in a resident population during the non-breeding season. Southwestern Naturalist 53:29–33.

LANTZ, S. J. AND C. J. CONWAY. 2009. Factors affecting daily nest survival of Burrowing Owls within black-tailed prairie dog colonies. Journal of Wildlife Management 73:232–241.

LEHMAN, R. N., K. STEENHOF, M. N. KOCHERT, AND L. B. CARPENTER. 1999. Effects of military training activities on shrub-steppe raptors in southwestern Idaho, USA. Environmental Management 23:409–417.

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

MACCRACKEN, J. G., D. W. URESK, AND R. M. HANSEN. 1985. Vegetation and soils of Burrowing Owl nest sites in Conata Basin, South Dakota. Condor 87:152–154.

MANNING, J. A. 2011. Factors affecting detection probability of Burrowing Owls in southwest agroecosystem environments. Journal of Wildlife Management 75:1558–1567.

MANNING, J. A. AND E. O. GARTON. 2012. A sightability model for correcting visibility and availability biases in standardized surveys of breeding Burrowing Owls in southwest agroecosystem environments. Journal of Wildlife Management 76:65–74.

MANNING, J. A. AND R. S. A. KALER. 2011. Effects of survey methods on Burrowing Owl behaviors. Journal of Wildlife Management 75:525–530.

MARTIN, D. J. 1973. Selected aspects of Burrowing Owl ecology and behaviour in central New Mexico. Condor 75:446–456.

MCCAIN, L., R. P. READING, AND B. J. MILLER. 2013. Prairie dog gone: livestock and exotic weeds in the Intermountain West. www.publiclandsranching.org/htmlres/wr_prairie_dog_gone.htm (accessed 7 Oct 2013).

MILLSAP, B. A. 2002. Survival of Florida Burrowing Owls along an urban-development gradient. Journal of Raptor Research 26:3–10.

MORRIS, W., D. DOAK, M. GROOM, P. KARUEVA, J. FIEGERG, L. GERBER, P. MURPHY, AND D. THOMSON. 1999. A practical handbook for population viability analysis. The Nature Conservancy, Arlington, USA.

MOULTON, C. E., R. S. BRADY, AND J. R. BELTHOFF. 2004. Territory defense of nesting Burrowing Owls: responses to simulated conspecific intrusion. Journal of Field Ornithology 75:288–295.

MOULTON, C. E., R. S. BRADY, AND J. R. BELTHOFF. 2006. Association between wildlife and agriculture: underlying mechanisms and implications in Burrowing Owls. Journal of Wildlife Management 70:708–716.

MRYKALO, R. J., M. M. GRIGIONE, AND R. J. SARNO. 2007. Home range and dispersal of juvenile Florida Burrowing Owls. Wilson Journal of Ornithology 119:275–279.

MURPHY, R. K., K. W. HASSELBLAD, C. D. GRONDAHL, J. G. SIDLE, R. E. MARTIN, AND D. W. FREED. 2001. Status of the Burrowing Owl in North Dakota. Journal of Raptor Research 35:322–330.

MURRAY, G. A. 1976. Geographic variation in the clutch size of seven owl species. Auk 93:602–613.

NATURESERVE. 2009. An online encyclopedia of life. Version 7.1. NatureServe, Arlington, Virginia, USA. www.natureserve.org/explorer/index.htm (accessed 4 Apr 2013).

NATURESERVE. 2013. NatureServe climate change vulnerability index. Version 2.1. NatureServe, Arlington, Virginia, USA. connect.natureserve.org/science/climate-change/ccvi (accessed 17 Oct 2013).

PARDEICK K.L., M. MEYERS AND M. PAGÉN. 1996. Surveys of Puerto Rican Screech-owl populations in large-track and fragmented forest habitats. Wilson Bulletin 108:776–782.

PARTNERS IN FLIGHT (PIF). 2007. PIF landbird population estimates database. Rocky Mountain Bird Observatory. Brighton, Colorado, USA.

PEST MANAGEMENT REGULATORY AGENCY (PMRA). 1995. Carbofuran. Decision document E95-05. PMRA, Health Canada, Ottawa, Ontario.

PLUMPTON, D. L. 1992. Aspects of nest site selection and habitat use by Burrowing Owls at the Rocky Mountain Arsenal, Colorado. Thesis. Texas Tech University, Lubbock, USA.

PLUMPTON, D. L. AND R. S. LUTZ. 1993. Nesting habitat use by Burrowing Owls in Colorado. Journal of Raptor Research 27:175–179.

POISBLEAU, M., L. DEMONGIN, C. TROUVE, AND P. QUILLFELDT. 2009. Maternal deposition of yolk corticosterone in clutches of southern rockhopper penguins (*Eudyptes chrysocome chrysocome*). Hormones and Behavior 55: 500–506.

POULIN, R. G. AND L. D. TODD. 2006. Sex and nest stage differences in the circadian foraging behaviors of nesting Burrowing Owls. Condor 108:856-864.

POULIN, R. G., L. D. TODD, K. M. DOHMS, R. M. BRIGHAM, AND T. I. WELLICOME. 2005. Factors associated with nest- and roost-burrow selection by Burrowing Owls (*Athene cunicularia*) on the Canadian prairies. Canadian Journal of Zoology-Revue Canadienne De Zoologie 83:1373–1380.

POULIN, R. G., L. D. TODD, E. A. HAUG, B. A. MILLSAP AND M. S. MARTELL. 2011. Burrowing Owl (*Athene cunicularia*). The Birds of North America. Number 61.

RATCLIFF, B. D. 1986. The Manitoba Burrowing Owl survey, 1982–1984. Blue Jay 44:31–37.

RESTANI, M., L. R. RAU, AND D. L. FLATH. 2001. Nesting ecology of Burrowing Owls occupying black-tailed prairie dog towns in southeastern Montana. Journal of Raptor Research 35:296-303.

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

RICH, T. D., C. J. BEARDMORE, H. BERLANGA, P. J. BLANCHER, M. S. W. BRADSTREET, G. S. BUTCHER, D. W. DEMAREST, E. H. DUNN, W. C. HUNTER, E. E. IÑIGO-ELIAS, J. A. KENNEDY, A. M. MARTELL, A. O. PANJABI, D. N. PASHLEY, K. V. ROSENBERG, C. M. RUSTAY, J. S. WENDT, AND T. C. WILL. 2004. Partners in Flight North American Landbird Conservation Plan. Cornell Lab of Ornithology, Ithaca, USA.

RODGERS, J. A., JR. AND H. T. SMITH. 1995. Set-back distances to protect nesting bird colonies from human disturbance in Florida. Conservation Biology 9:89–99.

ROSENBERG, D. K. AND K. L. HALEY. 2004. The ecology of Burrowing Owls in the agroecosystem of the Imperial Valley, California. Studies in Avian Biology 27:120–135

SAUER, J. R., J. E. HINES, J. E. FALLON, K. L. PARDIECK, D. J. ZIOLKOWSKI, JR., AND W. A. LINK. 2012. The North American Breeding Bird Survey, Results and Analysis 1966–2011. Version 12.13.2011. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

SCHNEIDER, R., K. STONER, G. STEINAUER, M. PANELLA, AND M. HUMPERT. 2011. The Nebraska Natural Legacy Project: State Wildlife Action Plan. 2nd Edition. The Nebraska Game and Parks Commission, Lincoln, USA.

SCOBIE, C., A. MARSH, AND R. FISHER. 2013. Influence of petroleum development on Burrowing Owl ecology. University of Alberta, Edmonton, Canada. www.ptac.org/attachments/1166/download (accessed 31 Oct 2013).

SHARPE, R. S., W.R. SILCOCK, AND J. G. JORGENSEN. 2001. Birds of Nebraska: their distribution and temporal occurrence. University of Nebraska Press, Lincoln, USA.

SHYRY, D. AND L. D. TODD. 2000. Juvenile Burrowing Owl demographics and movements: a summary of productivity, recruitment, post-fledging mortality, and dispersal in the Saskatchewan and Alberta populations. Unpublished report for the Endangered Species Recovery Fund.

SIBLEY, D. A. 2000. The Sibley guide to birds. National Audubon Society. Chanticleer Press, Inc., New York, USA.

SIDLE, J. G., M. BALL, T. BYER, J. J. CHYNOWETH, G. FOLI, R. HODORFF, G. MORAVEK, R. PETERSON, AND D. N. SVINGEN. 2001. Occurrence of Burrowing Owls in black-tailed prairie dog colonies on Great Plains National Grasslands. Journal of Raptor Research 35:316–321.

SILVA, S. I., I. LAZO, E. SILVA-ARANGUIZ, F. M. JAKSIC, P. L. MESERVE, AND J. R. GUTIERREZ. 1995. Numerical and functional response of Burrowing Owls to long-term mammal fluctuations in Chile. Journal of Raptor Research 29:250–255.

SMALLWOOD, K. S., C. G. THELANDER, M. L. MORRISON, L. M. RUGGE. 2007. Burrowing owl mortality in the Altamont Pass wind resource area. Journal of Wildlife Management 71:1513–1524.

SMITH, K. S. 1993. Owl pellets reveal *Cryptotis parva*, a new record for Caddo County, Oklahoma. Proceedings of the Oklahoma Academy of Science 73:29–30.

SMITH, M. D. 2004. Function of manure-scattering behavior of Burrrowing Owls (*Athene cunicularia*). Thesis. University of Arizona, Tucson, USA.

SMITH, B. W. AND J. R. BELTHOFF. 2001a. Effects of nest dimensions on use of artificial burrow systems by Burrowing Owls. Journal of Wildlife Management 65:318–326.

SMITH, B. W. AND J. R. BELTHOFF. 2001b. Burrowing Owls and development: short distance nest burrow relocation to minimize construction impacts. Journal of Raptor Research 35:385–391.

STAPP, P. M. F. Antolin, and M. Ball. 2004. Patterns of extinction in prairie dog metapopulations: plague outbreaks follow El Niño events. Frontiers in Ecology and the Environment 2:235–240.

STEVENS, A. F. J., E. M. BAYNE, AND T. I. WELLICOME. 2011. Soil and climate are better than biotic land cover for predicting home-range habitat selection by endangered Burrowing Owls across the Canadian prairies. Biological Conservation 144:1526–1536.

THIELE, J. 2012. Burrowing Owl distribution and nest site selection in western South Dakota. Thesis. South Dakota State University, Brookings, USA.

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

TIPTON, H. C., V. J. DREITZ, AND P. F. DOHERTY, JR. 2007. Occupancy of Mountain Plover and Burrowing Owl in Colorado. Journal of Wildlife Management 72:1001–1006.

TODD, D. 2001. Survival and dispersal of juvenile Burrowing Owls (*Athene cunicularia*) during the post-fledging, pre-migratory period. Thesis. University of Regina, Saskatchewan, Canada.

TORRES, I., A. ARRIZABALAGA, AND C. FLAQUER. 2004. Three methods for assessing richness and composition of small mammal communities. Journal of Mammalogy 85:524–530.

TUBELIS, D. P. AND W. B. C. DELITTI. 2010. Fire management and the nesting of *Athene cunicularia* (Aves, Strigidae) in grasslands in central Cerrado, Brazil. Biota Neotropica 10:93–101.

U. S. ENVIRONMENTAL PROTECTION AGENCY. 1996. Strychnine: Reregistration eligibility decision (R. E. D. facts). Prevention, pesticides, and toxic substances (7508W). Office of Pesticide Programs, U. S. Environmental Protection Agency, Washington D.C., USA. www.epa.gov/oppsrrd1/REDs/factsheets/3133fact.pdf (accessed 1 Nov 2013).

U. S. FISH AND WILDLIFE SERVICE. 2008. Birds of conservation concern 2008. U. S. Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, Virginia, USA. www.fws.gov/migratorybirds/NewReportsPublications/SpecialTopics/BCC2008/BCC2008.pdf

VERBOVEN, N., J. VERREAULT, R. J. LETCHER, G. W. GABRIELSEN, AND N. P. EVANS. 2008. Maternally derived testosterone and 17βestradiol in the eggs of Arctic-breeding Glaucous Gulls in relation to persistent organic pollutants. Comparative Biochemistry and Physiology, Part C 148:143–151.

VOS, D. K., R. A. RYDER, AND W. D. GRAND. 1985. Response of breeding Great Blue Herons to human disturbance in northcentral Colorado. Colonial Waterbirds 8:13–22.

WEDGWOOD, J. A. 1976. Burrowing Owls in south-central Saskatchewan. Blue Jay 34:26–44.

WELLICOME, T. I. 1994. Is reproduction in Burrowing Owls limited by food supply? Picoides 7:9-10.

WELLICOME, T. I. 1997a. Reproductive performance of Burrowing Owls (*Speotyto cunicularia*): effects of supplemental food. Pages 68–73 *in* The Burrowing Owl, its biology and management: including the Proceedings of the First International Symposium (J. L. Lincer and K. Steenhof, Editors). Raptor Research Report Number 9.

WELLICOME, T. I. 1997b. Status of the Burrowing Owl (*Speotyto cunicularia hypugaea*) in Alberta. Wildlife Status Report Number 11. Alberta Environmental Protection, Wildlife Management Division, Edmonton, Alberta.

WELLICOME, T. I. 2000. Effects of food on reproduction in Burrowing Owls (*Athene cunicularia*) during three stages of the breeding season. Dissertation. University of Alberta, Edmonton, Canada.

WELLICOME, T. I. AND E. A. HAUG. 1995. Second update of status report on the Burrowing Owl, *Speotyto cunicularia*, in Canada. Committee on the status of endangered wildlife in Canada, Ottawa, Ontario.

WELTY, J. L. 2010. Costs and benefits of variable nest density in Burrowing Owls: effects on predation, ectoparasites, egg yolk hormones, and productivity. Thesis. Boise State University, Idaho, USA.

WELTY, J. L., J. R. BELTHOFF, J. EGBERT, AND H. SCHWABL. 2012. Relationships between yolk androgens and nest density, laying date, and laying order in western Burrowing Owls (*Athene cunicularia hypugaea*). Canadian Journal of Zoology 90:182–192.

WHICKER, A. D. and J. K. Detling. 1988. Ecological consequences of prairie dog disturbances. BioScience 38:778–785.