SPECIES ASSESSMENT FOR WESTERN BURROWING OWL (*ATHENE CUNICULARIA HYPUGAEA*) IN WYOMING

prepared by

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Introduction

The Western Burrowing Owl (*Athene cunicularia hypugaea*), hereafter Burrowing Owl, is a diurnal bird of prey specialized for grassland and shrub-steppe habitats in western North America. The Latin species name for the Burrowing Owl, "*cunicularia*", means "little miner", referring to their unique behavior among North American raptors of nesting underground (Green 1988). Burrowing Owls will establish nests in earthen burrows, rock piles, eroded stream banks, and man-made structures such as roadside culverts and eroded irrigation ditches. Zuni Indians referred to the Burrowing Owl as the "priest of the prairie dogs", presiding on top of burrows within prairie dog colonies (*Cynomys* spp.) in the Great Plains (Haug et al. 1993). Since the time of early European exploration, Burrowing Owls have been discussed in association with prairie dog colonies in the West. On an expedition of the Rocky Mountain region in 1819, historian Dr. Edwin James comments:

> "In all the prairie-dog villages we had passed, small owls had been observed moving briskly about. One was here caught, and on examination found to be the species denominated Coquimbo, or burrowing owl. . . . This fellow citizen of the prairie dog, unlike its grave and recluse congeners, is of a social disposition, and does not retire from the light of the sun, but endures the strongest midday glare of that luminary, and is in all respects a diurnal bird. . . . With us the owl never occurred but in the prairie-dog villages, sometimes in a small flock, much scattered and often perched on different hillocks, at a distance, deceiving the eye with the appearance of the prairie dog itself, in an erect posture. . . . [They] rise upon the wing, uttering a note very like that of the prairie dog. . . . The burrows, into which we have seen the owl descend, resembled in all respects those of the prairie dog, leading us to suppose either that they were common, though, perhaps, not friendly occupants of the same burrow, or that the owl was the exclusive tenant of a burrow gained by the right of conquest" (Scheffer 1945).

The daytime activity and charisma of the Burrowing Owl afford it a conspicuous and appreciated role among humans. However, agricultural, industrial, and urban development throughout western North America have diminished available burrows and habitat for Burrowing Owls, and increased risks of mortality due to edge-effect predation, and exposure to pesticides and rodenticides (Haug et al. 1993, Klute et al. 2003, McDonald et al. *in press*). Recent range contraction and population declines have engendered conservation concern, as well as numerous studies examining the biology, demographics, and habitat use of Burrowing Owls throughout the West. This species assessment provides a synthesis of Western Burrowing Owl study results with regard to biology, conservation status, management and monitoring practices, and information needs, with particular reference to Burrowing Owl populations within Wyoming.

Natural History

Morphological Description

The Burrowing Owl is a small, ground-dwelling owl, with long legs, sparsely feathered from the metatarsus to the mid-toe (Figure 1, Figure 2). Total length for males is 19.5-25.0cm, females is 19.0-25.0; average mass is approximately 150g. Head is rounded and lacking ear tufts, chocolate-brown in female plumage and light brown to gray in males' worn plumage, with white streaking and or spotting on the crown of both sexes. The facial disk is oval, with a buff-colored eyebrow-to-malar stripe in the interior. Eyes are round with a bright yellow iris, bill is small and pale yellow-gray. Adults have a distinct white throat and buff-white belly with chocolate-brown barring and spotting, extending further down the belly in females. Wings are relatively long and narrow, with 10 brown and buff barred primaries and brown primary and secondary coverts streaked with buffy-white spots; average wing chord 165mm. Tail is short with 12 brown and buff barred retrices, and white undertail coverts; average tail length about 70mm. Scapulars brown;

heavily spotted with buff-white. Males are generally larger and lighter in color than females, although relative differences are difficult to detect from a distance (Figure 2).

Taxonomy and Distribution

A member of the owl family, Strigidae, taxonomic assignment of the Burrowing Owl has varied between two genera: *Speotyto* and *Athene*. Fossil history indicates the closest ancestor to the Burrowing Owl was *Speotyto megalopeza*, occurring in late-Pleistocene deposits in Kansas (Ford 1966). Until 1983, the Burrowing Owl remained in the monotypic genus *Speotyto*, at which time the genus was changed to *Athene* (shared with 3 palearctic congenors: *A. brama* (Little Spotted Owl), *A. noctua* (Old World Little Owl), *A. blewitti* (Forest Owlet)) (American Ornithologists' Union 1983, Haug et al. 1993). Based on karyotypic evidence, generic designation was changed back to *Speotyto* in 1991(American Ornithologists Union 1991). The most recent replacement into the genus *Athene* is likely based on external ear structure, and similarity in vocalizations with other members of *Athene* (Haug et al. 1993, McDonald et al. *in press*).

Eighteen subspecies of Burrowing Owl are currently recognized and are distinguished by plumage and size differences, and geographic isolation (Haug et al. 1993, Clark et al.1978, Peters 1940). In North America, there are two subspecies, the Western Burrowing Owl, *Athene cunicularia hypugaea*, and the Florida Burrowing Owl *A. c. floridana*. Strong genetic evidence supports the split of the Western and Florida subspecies of Burrowing Owls (Korfanta 2001, Desmond et al. 2001). Geographic separation and some behavioral differences (e.g. Florida Burrowing Owls dig their own burrows whereas Western Burrowing Owls are dependent on fossorial mammals to leave empty burrows), also lend evidence to the distinction between subspecies. The subspecies found in Wyoming is *A.c. hypugaea*.

Global Distribution

Burrowing Owls are distributed throughout North, Central, and South America (Figure 4). In the eastern Americas, Burrowing Owls are found in Florida, Hispaniola, northern Lesser Antilles, and the Bahamas. In the western Americas, Burrowing Owls are found from central Alberta to Tierra del Fuego in South America. Range contractions have occurred at the periphery of the distribution of the Western Burrowing Owl in North America, primarily in Saskatchewan, Manitoba, and several mid-western United States from Minnesota down through Texas (Figure 5).

Population Connectivity

Continuity of Burrowing Owl habitat has been disrupted by urban and agricultural development, and by reductions of colonies of burrowing mammals (Butts 1973, Zarn 1974, Haug et al. 1993). Historically found in natural habitat types of grassland and shrub steppe, Burrowing Owls are now commonly found in isolated patches of intact habitat as well as altered landscapes at the periphery of urban and agricultural centers (Warnock and James 1997). To date, the effect of isolation on population genetics has been negligible. If populations of owls become physically isolated from one another, they may become genetically isolated and subject to the vulnerabilities associated with small populations. However, Korfanta (2001) found that among 15 different populations of Western Burrowing Owl, there was little genetic differentiation and populations were essentially panmictic. The lack of genetic difference among populations suggests high mobility of individual owls among populations, and frequent long-distance dispersal events (Korfanta 2001). Korfanta’s (2001) examinations included 4 populations from Wyoming, which showed low genetic differences and high outbreeding levels. While habitat fragmentation has not yet shown to have a negative impact on population connectivity, urban development, resource development, and fragmentation of prairie dog colonies is increasing within the Rocky Mountain region (Zarn 1974, Butts 1973, Flath and Clark 1986, Sidle et al. 2001). As such, continued monitoring of the connectivity of Burrowing Owl populations has value.

Regional Distribution

Currently, accurate information on the distribution of Burrowing Owls within Wyoming is lacking. The information that does exist in three forms: 1.GAP data of potential Burrowing Owl habitat in Wyoming (Figure 6; http://www.gap.uidaho.edu/Projects/States/), 2. owl sightings from the Wyoming Game and Fish Wildlife Observation database (Figure 7; Korfanta et al. 2001), and 3. Annual surveys within the Thunder Basin National Grasslands, northeast Wyoming (Figure 8; Conway and Hughes 2001, Conway and Lantz 2002, Conway and Lantz 2003).

GAP analysis uses a predictive model to determine distributions of vertebrate species based on existing survey and species-habitat information. The GAP map of Burrowing Owl distribution within Wyoming is based on actual locations and predicted locations given primary and secondary habitat cover types that owls are known to inhabit. The broad scale of habitat requirements used to generate this map likely overestimates the actual distribution of Burrowing Owls within Wyoming, as it lacks the finer-scale habitat preferences of the species (e.g. prairie dog colonies). However, the Wyoming GAP map (Figure 6) does provide a coarse filter for prioritizing future survey efforts within appropriate habitat types.

The Wyoming Game and Fish Wildlife Observation (WOS) database consists of wildlife sightings reported voluntarily by professional biologists as well as amateur wildlife watchers and interested citizens. When systematic survey efforts are lacking, voluntary reports of sightings may be a way to roughly determine distribution and population trend for the species. In 1999, Korfanta et al. (2001) combined historical reports of Burrowing Owl locations with results from survey efforts to produce a distribution map for Wyoming (Figure 6). The map shows owl sightings throughout most of the lower elevation areas within the state, with higher concentrations in the east. Korfanta et al. (2001) cautions against using the WOS as the sole source for distributional information, as the records do not represent a systematic sampling effort and the voluntary reports may lead to a biased distribution. For example, areas near urban centers may show high Burrowing Owl densities because of their easy access, not necessarily because the densities are actually higher relative to the surrounding landscape (Korfanta et al. 2001).

Systematic surveys for Burrowing Owls have been conducted within the Thunder Basin National Grasslands in northeastern Wyoming from the years 2001 through 2004 (Figure 8; Conway and Hughes 2001, Conway and Lantz 2002, Conway and Lantz 2003, Conway and Lantz *unpubl. data*). While these efforts have been restricted to prairie dog colonies, the survey method is applicable to large-scale survey efforts. This method, included in Appendix I, provides a standardized method that maximizes detection while minimizing the temporal and spatial biases that characterize many species' distribution maps.

Habitat Requirements

The following discussion of habitat requirements for the Burrowing Owl are based on existing species assessments provided by the U.S. Fish and Wildlife Service (Klute et al. 2004), the U.S. Forest Service (McDonald et al. *in press*), and several other studies throughout western North America. While the following summary should not replace local studies of nest selection, a suite of important habitat indicators have been identified from a large body of literature:

- Open, dry, treeless areas on grasslands, shrublands, and desert floors,
- Gentle slopes, short vegetation, high percentages of bare ground,
- High densities of burrows,
- Current activity of burrowing mammals, primarily prairie dogs,
- Close proximity to other nesting Burrowing Owls,
- Dried manure from cows, horses, or bison.

Breeding macrohabitat

With a relatively wide-ranging distribution throughout the West, Burrowing Owls are considered to be habitat generalists. Burrowing Owl habitat typically consists of open, dry, treeless areas on plains, prairies, and desert floors (Figure 9; Haug et al. 1993, Klute et al. 2003). While owls historically occurred within undisturbed grasslands and shrublands, they are now frequently encountered in disturbed, human-altered landscapes such as farms, golf courses, campuses, airports, and residential areas (Haug et al. 1993, Thompson 1971, Warnock and James 1997, Clayton and Schmutz 1999, Orth and Kennedy 2001).

Breeding microhabitat

Burrowing Owls spend a considerable amount of time on or in the ground, and require high visibility for detection of both predators and prey (Haug et al. 1993). Level to gentle slopes, short vegetation, and high percentages of bare ground are key indicators of Burrowing Owl habitat (MacCracken et al. 1985, Green and Anthony 1989, Haug et al. 1993, Klute et al. 2003). Given their reliance on a short vegetation component, Burrowing Owls are commonly found in association with high-intensity grazers, such as bison (*Bison bison*), prairie dogs, ground squirrels (*Spermophilus* sp.), domestic cattle, and other grazers that clip vegetation (Konrad and Gilmer 1984, MacCracken et al. 1985). In a Colorado population, were significantly ($P < 0.05$) more likely to nest in burrows that had lower grass height and more bare ground than control sites (Plumpton and Lutz 1993). MacCracken et al. (1985) found that owl-occupied burrows in South Dakota were in an early stage of plant succession (relative to the surrounding prairie) following recent prairie dog grazing; nest burrows had greater forb cover but lower vegetation height than unoccupied burrows. The authors speculated that forb cover might provide concealment for emerging owlets. However, in subsequent years when vegetation height increases and abandoned burrows collapse, owls may nest in different burrows within the same or different (more active) prairie dog colonies (Conway and Lantz 2003).

The presence of burrows is the most essential component of Burrowing Owl habitat; burrows are used for nesting, roosting, cover, and caching prey (Coulumbe 1971, Martin 1973, Green and Anthony 1989, Haug et al. 1993). However, owls do not normally dig their own burrows (Floridian subspecies excluded, see Millsap 1996), therefore select their habitat primarily on the presence of burrowing animals such as prairie dogs, ground squirrels, badgers, marmots, coyotes, and tortoise (Green and Anthony 1989, Haug et al. 1993). In human-altered landscapes, the use of earthen burrows can be mitigated by the presence of artificial burrows, metal culverts, and eroded fissures in irrigation canals, and disturbed soils (Trulio 1995, Belthoff and King 2002).

Burrowing Owls not only require burrows for nesting, they select burrows in close proximity to other usable burrows – called 'satellite' burrows (Haug et al. 1993, Desmond and Savidge 1999). Satellite burrows are used primarily as cover for juvenile owls post-fledge, but are also used by adult owls for cover, prey cache sites, and roosts from which the male may guard the nest burrow. In an experimental test in a grassland system in California, Ronan (2002) blocked entrances to satellite burrows at Burrowing Owl nest sites and observed significant movements (mean = 68m) of the owl family groups out of the natal area in response. In an Idaho population of Burrowing Owls where badger burrows were the primary excavator, juveniles used an average of three satellite burrows within their natal areas for roosting before permanently dispersing (King and Belthoff 2001). Within prairie dog colonies in Nebraska, juvenile owls used an average of 10 burrows near the primary nest burrow (Desmond and Savidge 1999). Within prairie dog colonies in Wyoming, Burrowing Owl family groups used an average of 9 burrows within the natal area (Lantz and Conway *unpubl. data 2003*). Within this Wyoming population, owls nested in areas with higher burrow density (28 burrows within 30-m radius) relative to unused, available burrows (18 burrows within 30-m radius) (t=-4.14, p=0.000) (Lantz and Conway *unpubl. data 2003*). Selection of nest sites within areas of higher burrow density may provide more available burrows for 'satellite' use during the breeding season.

In the Great Plains, Burrowing Owls show preference for nesting within active or very-recently abandoned colonies of black-tailed prairie dogs (*C. ludovicanus*) (Butts and Lewis 1982, Toombs 1997, James and Espie 1997, Desmond and Savidge 1996, Desmond et al. 2000, Sidle et al. 2001). In the panhandle of Oklahoma, Butts and Lewis (1982) found 66% of adult Burrowing Owls were breeding in colonies active with black-tailed prairie dogs, though active colonies comprised only 0.16% of the study area. Within three years of cultivation or poisoning of those prairie dog colonies, prairie dog activity ceased and owls no longer nested within the colonies (Butts and Lewis 1982). Burrowing Owl avoidance of those inactive colonies was likely due to collapsed burrows (decreased burrow availability) and increased vegetation height (Butts and Lewis 1982). In a survey of prairie dog colonies in Colorado, Plumpton and Lutz (1993) found owls nesting exclusively within active prairie dog colonies. The authors attributed this pattern to the high burrow density and short vegetation height characteristic of active prairie dog colonies. Plumpton and Lutz also found that within a 14-year study on the Rocky Mountain Arsenal, Burrowing Owl nest densities tracked fluctuations in active prairie dog colony area (Antolin et al. 2002). Similarly, a 7-year study in western Nebraska documented a 63% decline in nesting pairs was positively correlated with a decline in usable burrows within exterminated prairie dog colonies (Desmond et al. 2000). While prairie dogs provide the structural characters for Burrowing Owl nest-site selection, indirect benefits of prairie dog activity have been suggested. Burrowing Owls may be responding to the predator-alarm calls of prairie dogs, and may benefit from a dilution effect as predators will likely choose the prey of higher density (prairie dogs) (Desmond et al. 2000). However, these possibilities have not yet been quantified.

In addition to the overall activity of the prairie dog colony, Burrowing Owls tend to nest near active prairie dog burrows (Hughes 1993, Desmond et al. 2000, Restani et al. 2001). Restani et al. (2001) observed Burrowing Owl nest burrows significantly closer to active prairie dog burrows than to inactive ones (14.6 m and 21.8 m, respectively; $P = 0.08$). Desmond et al. (2000) found that successful nests (fledging ≥1 juveniles) had an average of 96 active prairie dog burrows within 75m of the nest, while unsuccessful nests had an average of 26. Burrowing Owls may select nest sites near active prairie dog burrows because in the absence of prairie dogs, vegetation around burrows may become too tall to be suitable for nesting (Butts and Lewis 1982, Plumpton and Lutz 1993).

Burrowing Owls may nest solitary or in loose aggregations or clusters, and the presence of conspecifics may influence where an owl selects its nest (Haug et al. 1993). Burrowing Owls have shown patterns of coloniality in several populations: Wyoming (Conway and Lantz 2002, 2003), Nebraska (Desmond et al. 1995), Oregon (Green and Anthony 1989), Montana (Restani et al. 2001), and California (Rosenberg and Haley *in press*). Some studies suggest that Burrowing Owl nest density is influenced primarily by the distribution of burrows, and the clumped distribution of burrows is due to the coloniality of the primary excavator (Green and Anthony 1989, as cited within McDonald et al. *in press*). However, Desmond et al. (1995) found that nests are clumped even within large prairie dog colonies, where vacant burrows are available across large areas. Coloniality in Burrowing Owls usually results in brood mixing among nests (Johnson 1997, Lantz and Conway, *unpubl. data*), and may elicit vigilance from predators even by unrelated adults.

Other factors that may influence Burrowing Owl nest-site selection include soil type, perch distance, and the presence of dried cow, horse, or bison manure. Soil texture may indirectly influence owl nest selection by affecting burrowing mammal colonization. In southeastern Colorado, Toombs (1997) found that prairie dogs avoided soils with high coarse material content, and thus owls were not selecting nests within coarse soils (presumably due to low burrow availability). However, a direct selection for soil type by Burrowing Owls has not been documented, and observed patterns (MacCracken et al. 1985, Toombs 1997) may co-vary with other effects of burrowing mammals (e.g. short vegetation, burrow availability).

With regard to selection or avoidance of perches, study results conflict. Burrowing Owls are often observed using perches for roosting, hunting, or nest vigilance (Rodriquez-Estrella and Ortega-Rubio 1993, Clayton 1997, Lantz *personal observation*). However, perch avoidance has been documented in Colorado (Plumpton and Lutz 1993) and Oregon (Green and Anthony 1989). In both studies, researchers found that when vegetation was less than 8cm, elevated perches were not typically used. In Wyoming, preliminary analyses show that the distance to the nearest perch is greater for nest burrows (115m) relative to unused burrows (93m), although results are not statistically significant (Lantz *unpubl. data*).

A relatively unique behavior of the Burrowing Owl is that paired males often line their nest burrows with dried manure from cows, horses, and bison (Smith 2004). Previously, biologists assumed that owls lined their nest burrows with dried manure to mask the olfactory identification of the nest from predators but that was largely based upon conjecture offered in one study (Green and Anthony 1989). However, recent experiments show that manure lining does not change the probability of depredation of nests, but does increase density and biomass of the primary prey: insects (Smith 2004). Smith (2004) found that manure-lined burrows supported 76% more insect biomass than did un-lined burrows. Males typically line nest burrows with manure during egg-laying, incubation, and nestling stages, attracting high-calorie prey to the female and nestlings without risk or energy expenditure (Smith 2004). As such, the spread of dried manure among known Burrowing Owl nest areas or artificial nest areas has been suggested as a management strategy.

Wintering Habitat

Despite the wealth of existing information on patterns of habitat selection on the breeding grounds, there is a paucity of information about patterns of habitat selection on the wintering grounds. Very few studies have been published on any aspect of Burrowing Owl wintering ecology (Rodriquez-Estrella and Ortega-Rubio 1993, Holroyd et al. 2001). Primary wintering grounds are thought to occur in Mexico and Central America, and very little quantitative information is available. Limited data shows an increased use of agricultural areas and culverts, as well as use of dune vegetation and woody debris (Haug et al. 1993, Klute et al. 2003). Management directives and conservation strategies should include international cooperation for research within the wintering range (Holroyd et al. 2001).

Area Requirements

Home range estimates are limited to only a few published studies, and these estimates range from 45ha (Rosenberg and Haley *in press*) to 240ha (Haug and Oliphant 1990). Variation among estimates is likely a function of landscape characteristics, prey availability, and dynamic environments (Rosenberg and Haley *in press*), as well as the researcher's method of estimation. While Burrowing Owls remain near the nest burrow during daylight, they forage further from the nest at sunrise and sunset (Klute et al. 2003). Males tend to forage at distances further from the nest than do females (Thompson and Anderson 1988). In Saskatchewan, Haug and Oliphant

(1990) found that males (n=6) had home ranges of 14-480ha (mean=240ha), and that daytime activity usually occurred within 250m of the nest burrow. In the Imperial Valley of California, Rosenberg and Haley (*in press*) found that males (n=6) foraged primarily within 600m of the nest burrow (>80% of locations), but that occasional long-distance forays increased the estimation of home range. Within the Burrowing Owl population in Imperial Valley, male Burrowing Owls had home ranges ranging from 45.3ha (fixed kernel estimate – likely underestimates) to 184.5ha (adaptive kernel estimate – likely overestimates). Home range estimates within their study varied by method of estimation. It is important to note that these home range studies were located within agricultural landscapes: Saskatchewan was a mosaic of cereal crops and rangeland, while California was monoculture grass crops lined by concrete and earthen irrigation trenches. Haug (1985) observed that home range size for Burrowing Owls tends to increase with increasing intensity of cultivation, but currently there are no available estimates of Burrowing Owl space use within intact grasslands or shrublands for comparison.

Landscape Pattern

Once the primary components of nesting habitat have been met (high burrow density, short vegetation around nest), Burrowing Owls can be found in a variety of habitat types and landscapes. While open areas with short vegetation are critical for nesting and roosting, there is some evidence that Burrowing Owls prefer a vegetation mosaic with nesting habitat interspersed within taller vegetation for hunting (Clayton and Schmutz 1999). Tall vegetation may provide the cover necessary to host large populations of rodents, which are then susceptible to predation as they traverse open areas in the mosaic (Clayton and Schmutz 1999). Very low vegetation and sites with exposed soils are habitat for grasshoppers, another important prey item that may be supported in a vegetation mosaic (Clayton and Schmutz 1999).

In agricultural areas, Burrowing Owl habitat use depends on the mosaic patterns and the degree of cultivation. In intensely cultivated areas, owls will nest along bare, exposed irrigation trenches while foraging on the wing over the cultivated fields (Haug and Oliphant 1990, Rosenberg and Haley *in press*). Cultivated areas tend to support high densities of deer-mice (*Peromyscus* spp.) and voles (*Microtus* spp.) via increased water (irrigation) and vegetal cover, and owls will use these areas for foraging (Haug and Oliphant 1990, Clayton and Schmutz 1997, Rosenberg and Haley *in press*). In less-intensively cultivated areas, where a mosaic of rangeland or intact prairie exists among cultivated areas, owls tend to avoid the cultivated areas when nesting and foraging, showing preference for undisturbed tracts of land (Haug and Oliphant 1990, Clayton and Schmutz 1997).

In a Saskatchewan study, Burrowing Owls preferred habitat continuity, and the persistence of breeding pairs decreased with increased habitat fragmentation (Warnock 1997, Warnock and James 1997). In Colorado, Orth and Kennedy (2001) found that owls frequently occurred within prairie dog colonies surrounded by fragmented habitat, but distances between patches of intact habitat were shorter than in unoccupied areas. The authors speculated that owls prefer large, yet fragmented patches of shortgrass, as the increased amount of edge is associated with increased abundances of arthropod and mammalian prey (Orth and Kennedy 2001). While owls were present within highly-fragmented landscapes in both studies, caution should be taken in the interpretation. Fragmented landscapes may temporarily contain high densities of Burrowing Owls, but intense fragmentation and patch isolation can create sink habitats (see Pulliam 1988).

Movement and Activity Patterns

Daily Activity

Depending on the time of year, Burrowing Owls are known to be diurnal, crepuscular, and/or nocturnal (Haug et al. 1993). Primary foraging times have been documented at sunrise and sunset (Coloumbe 1971, Thompson and Anderson 1988), but long-distance nocturnal hunting bouts have been documented for males (Haug and Oliphant 1990). During incubation, the male is visible throughout the day roosting as a sentry at a nearby satellite, while the female remains underground for long stretches of time (Coloumbe 1971, McDonald et al. *in press*). During the nestling and fledgling periods, the male can be seen hunting throughout the day, delivering prey to the female and nestlings in the nest burrow (Lantz *personal observation*). In the late summer, pre-dispersal stage of the breeding season, Burrowing Owls limit their mid-day activity as juveniles and adults roost in the shaded entrances of satellite burrows, emerging at sunrise and sunset to forage as family groups (McDonald et al. *in press*).

Migration

Very little information is available on migration routes and times. Burrowing Owls that breed in the northern United States and Canada are thought to migrate south during September and October, returning to the breeding grounds during March through May (Klute et al. 2003). Banded owls from Wyoming, South Dakota, Nebraska, Colorado, and Kansas have been recovered in Oklahoma, Texas, Arkansas, and Mexico. Bands from the northern Great Plains (primarily Canada) have been recovered in Nebraska, Kansas, and Texas. Burrowing Owls from eastern Washington, Oregon, and British Columbia make coastal movements into California (Klute et al. 2003). While most winter band recoveries are from the southern plains and the southwestern United States, Mexico is thought to contain large populations of wintering owls

(Rodriquez-Estrella and Ortega-Rubio 1993, Haug et al. 1993, Holroyd et al. 2001, Klute et al. 2003).

Between-year Dispersal

Site- and mate-fidelity has been documented for both resident and migrant populations of Burrowing Owls (Rosenberg and Haley *in press*, Lutz and Plumpton 1999, respectively). Within a California population, among resident owls of known sex observed in 2 successive years (n=91 [1998-1999], and n=83 [1999-2000]), 85% re-nested within 400m of the previous year's nest (Rosenberg and Haley *in press*). Within an annually migratory population of owls in Colorado, 75% of known-sex owls (n=42 [1990-1994]) returned to breed in formerly-used sites (Lutz and Plumpton 1999). However, re-encounter rate was significantly higher for the resident population (of 239 adult owls banded 140 were re-encountered annually) than for the migrant population (of 555 adult owls banded 42 were re-encountered in 4 subsequent years). Thus, while both populations exhibited strong philopatry among re-observed owls, fewer banded adults were returning annually to the breed among the migrant population. It is possible that breeders within the migrant population move undetectably large distances between breeding seasons. Long-distance dispersal events are difficult to document, but the lack of genetic differentiation among populations of Burrowing Owls suggests that such movements may be maintaining high contemporary gene flow (Korfanta 2001).

Post-fledging Dispersal

While the end of juvenile dispersal for migratory bird populations is usually defined as the initiation of migration, defining the initiation of dispersal is not as clear. Age of juveniles at dispersal and dispersal distances can vary widely among studies. In addition, Burrowing Owlets spend much of their time on the ground using satellite burrows around the nest burrow, rendering determination of the fledgling period and dispersal period more difficult and variable than for tree-nesting or cavity-nesting birds (Todd 2001). For example, Todd (2001) defined dispersal initiation as the first movement of an owlet to a burrow other than its natal burrow (satellite burrow). As such, average age of juvenile dispersal for Todd's study population was 46 days (Saskatchewan, Todd 2001). However, King and Belthoff (Idaho, 2001) defined initiation of dispersal as a permanent movement >300m from the natal burrow (regardless of use of satellites <300m), and consequently documented an older average age of dispersal of 57 days.

Given Todd's (2001) definitions, she defines 3 patterns of dispersal of juvenile Burrowing Owls. 1) Nest-centered dispersal: juveniles remain close (within 139m) to the nest burrow until abruptly leaving the area for migration. 2) Single-roost dispersal: juveniles move to a non-nest burrow or cluster of burrows (average distance from nest = 859m) and remain at this single roost until initiating migration. 3) Multiple-roost dispersal: juvenile owls move in a stepwise pattern from burrow cluster to burrow cluster over the dispersal period, resulting in an average dispersal distance of 1534m. These three types of dispersal occurred in approximately equal proportion within the population ($\chi^2 = 0.071$, $p>0.05$), although single-roost dispersal was most common. King and Belthoff (2001) documented movement patterns similar to Todd's (2001) 'multiple-roost dispersal', noting that 88% of all telemetry locations were of juveniles using satellite burrows.

Reproduction

Breeding Behavior

Burrowing Owls are monogamous, although depredated and divorced mates are often replaced within the same breeding season (Haug et al. 1993, Martin 1973, see Haug 1985 for rare case of polygyny). During pair-bond formation, male courtship behavior includes display flights of hovering and circling, presentation of food to the female, and singing of the primary song: 'coo-

cooo' (Grant 1965, Thomsen 1971, Haug et al. 1993). While pair bonds remain intact throughout the breeding season, adults will change mates between breeding seasons (Martin 1973, Conway and Lantz *unpubl. data*).

Breeding Phenology

Resident populations often maintain pair bonds year-round (Haug et al. 1993, Rosenberg and Haley *in press*). In migratory populations, adults arrive on the breeding grounds singly or paired (Haug et al. 1993). Spring arrival dates for migratory individuals can vary: the first week of May in Saskatchewan (Haug et al. 1993), the last week in March in Washington (Smith 2004), early April in Wyoming (Conway and Lantz, *unpubl. data*). Male courtship and territorial display begins shortly after arrival (Haug et al. 1993), and manure scattering (nest building) at burrows begins approximately 9 days after female arrival (date of pair formation) (Smith 2004). Egg-lay dates vary: early April in California (Rosenberg and Haley *in press*), late March in New Mexico (Martin 1973), mid-May in Saskatchewan (Haug 1985), and late April-early May in Wyoming (Conway and Lantz *unpubl. data*). Incubation lasts 26-30 days (Klute et al. 2003), and nestlings can be seen above ground at 15 days post-hatch (Lantz *personal observation*). Fledge age varies by researcher interpretation: 32-40 days post-hatch in California (Ronan 2002), 42 days in Oregon (Green and Anthony 1989), 44 days in Arizona, Washington, and Wyoming (Conway, *personal communication 2004*).

Reproductive Success

Clutch size ranges from 1-12 eggs (Haug et al. 1993). Number of young fledged per nest also varies among populations, and number fledged is often much lower than number eggs produced. For example, average clutch size in Wyoming was 6 eggs, while the average number of young fledged (= 40 days) per nest was 3 owlets (Table 1; Conway and Hughes 2001, Conway and Lantz

2002, 2003). Average clutch size in Imperial Valley, California was 6 eggs, while the average number of young surviving to 14-21 days was 2.5 owlets (Rosenberg and Haley *in press*). Carrizo Plain National Monument, California reported similar survival rates to 14-21 days as 1.25-2.96 owlets per nest (Ronan 2002). Other reported fledge rates include: 3.6 in New Mexico (Martin 1973), 3.6 in Colorado (Lutz and Plumpton 1999), 1.9 in Nebraska (Desmond et al. 2001), and 2.9-4.9 in Canada (Haug et al. 1993).

Reproductive estimates for Burrowing Owls are difficult to obtain without bias because nests are underground (Gorman et al. 2003). In the absence of artificial nest burrows and infrared burrow videoscopes, reproductive rates are based on counts of young seen above ground (Thomsen 1971, Martin 1973, Haug 1985, Green and Anthony 1989, Lutz and Plumpton 1999, Desmond et al. 2000). However, above-ground counts are subject to biases from unequal observation effort, differences in sighting probability among observers, and the fact that complete broods are rarely all above the ground at the same time (Gorman et al. 2003). While all current field methods for estimating reproductive success in Burrowing Owls have a negative bias, Gorman et al. (2003) have shown that the most reliable estimates can be achieved through repeated nest visits, with direct observation of the maximum number of young seen above ground.

Population Demographics

Fecundity

Adults are capable of breeding annually, beginning at age 1yr (Haug et al. 1993). Female clutch sizes range from 1-12 eggs, and fledge rates range from 1.25 – 4.9 owlets (see above). Annual reproductive success rates vary among populations, and vary among methods of estimation, but have been reported between 33% and 100% (Haug et al. 1993). Clutch size and number of young fledged have been shown to vary significantly with prey abundance (Wellicome et al. 1997, Haley 2001).

Survivorship

Survival of adult Burrowing Owls has been estimated with capture-recapture models (Lutz and Plumpton 1997, Rosenberg and Haley *in press*) and with probabilities derived from radio telemetry observations (Clayton and Schmutz 1997). Lutz and Plumpton (1997) found that 'after hatch-year' adults in Colorado had a weighted average annual survival rate (1990-1994) of 0.37, or 37% survival. Rosenberg and Haley (*in press*) found an apparent annual survival rate of adult male Burrowing Owls in California to be 0.64 (64% survival), and an annual survival rate for females of 0.58 (although 95% confidence intervals overlapped for males and females). In Alberta and Saskatchewan, mean annual survival of adult females was estimated at 0.83, and males at 0.48 (Clayton and Schmutz 1997). Return rates of banded adults in Saskatchewan were 37-51% over 4 breeding seasons suggesting breeding adults could survive to at least age 4yr, and one banded wild bird survived to age 8yr (Haug et al. 1993).

The post-fledging, premigratory survival of juvenile Burrowing Owls has been shown to have significant impacts on population dynamics (Clayton and Schmutz 1999, King and Belthoff 2001, Todd et al. 2003). Survival during this life stage may be a limiting factor in the population growth rate. In Saskatchewan, Todd et al. (2003) documented 100% survival of juveniles in 1997; then documented a 45% mortality rate for premigratory juveniles from 1998-2000. When juvenile survival was 100% in 1997, Todd et al. (2003) found that the overall population of Burrowing Owls increased by 32% between 1997 and 1998. When survival was reduced by almost one half (1998-2000), the overall population decreased by 11-48% in subsequent years. Juvenile recruitment into the breeding population was highest in 1998 (following high juvenile survival in

1997) at 8.3%, but then averaged 2.1% in subsequent years. The authors note that while these results are correlative and other factors contribute to population fluctuation, it did appear as though post-fledging juvenile survival was influencing population stability. The juvenile Burrowing Owl survival rate of 100% in 1997 coincided with a 28-year high in vole abundance on the Canadian Prairie (Todd et al. 2003). While voles normally account for a relatively small portion of owl diet (0-32%), in 1997 voles comprised 87% of Burrowing Owl diet. Todd et al. (2003) concluded that the availability of prey in the post-fledging period plays an important role in juvenile survival and population regulation.

Limiting Factors

In addition to the importance of juvenile survival, stochastic analyses in matrix population models have identified adult annual survival (especially female) as a critical life stage for stability and growth of Burrowing Owl populations (see McDonald et al. *in press* for full matrix population analyses). Habitat loss and fragmentation are the limiting forces. The direct loss of habitat may be limiting breeding sites as well as important cover and hunting sites in wintering areas (Holroyd et al. 2001, Klute et al. 2003). Indirect effects of habitat fragmentation may also limit adult and juvenile survival in several ways: 1) increased mortality due to vehicular collision, 2) increased pressure and mortality from predators (see *Community Ecology* section for full list of potential predators), and 3) increased intraspecific competition (Clayton and Schmutz 1999, Warnock and James 1997, Orth and Kennedy 2001). As previously discussed, prey availability may also be an important limiting factor affecting survival of adults and juveniles (Wellicome 1997, Haley 2001, Poulin et al. 2001, Todd et al. 2003).

Metapopulation Dynamics

High levels of gene flow, frequent breeding and natal dispersal, and flexibility in patterns of landscape use suggest that metapopulation dynamics are not likely to be a feature of Burrowing Owl populations (McDonald et al. *in press*). Local extinctions may occur in peripheral populations near edges of the range, particularly where habitat is marginal (McDonald et al. *in press*). Fluctuations among populations are likely in portions of the range where Burrowing Owls are strongly associated with prairie dog colonies, and a greater understanding of owl movement among prairie dog colonies is needed (McDonald et al. *in press*).

Food Habits

Diet

Burrowing Owls are opportunistic feeders; major food items are invertebrates, small mammals, and small birds; reptiles and amphibians occasionally taken (Haug et al. 1993). Invertebrates are taken with the greatest frequency within the Burrowing Owl diet, contributing less to overall biomass. Invertebrates accounted for 88% if diet and 5% of biomass in Wyoming (Thompson and Anderson 1988), 92% of diet and 8% of biomass in Oregon (Green and Anthony 1989), 90% of diet and 9% of biomass in Colorado (Marti 1974). Primary arthropods within the Burrowing Owl diet include Orthoptera (grasshoppers and crickets), Coleoptera (beetles), Dermaptera (earwigs), Diptera (flies), and Hymenoptera (ants) (Thomsen 1971, Thompson and Anderson 1988, Rosenberg and Haley *in press*, Smith 2004). Small vertebrates are taken less frequently but comprise the majority of the biomass. Vertebrates accounted for 12% of diet but 95% of biomass in Wyoming, 8% of diet but 78% of biomass in Oregon (Green and Anthony 1989). Primary vertebrates included in the Burrowing Owl diet are small mammals: voles, ground squirrels (*Spermophilus* spp.), house mice (*Mus musculus*), pocket mice (*Perognathus* spp.), and deer mice (*Peromyscus maniculatus*) (Thompson and Anderson 1988, Rosenberg and Haley *in* *press*). Secondary vertebrates within the Burrowing Owl diet are small passerine birds: Horned Lark (*Eremophila alpestris*), Lark Bunting (*Clamospiza melanocorys*), and Lark Sparrow (*Chondestes grammacus*) (Thompson and Anderson 1988). Tiger salamanders (*Ambystoma tigrinum*), Plains spadefoots (*Spea bombifrons*), and Plains garter snake (*Thamnophis radix*) are occasionally taken (Lantz *personal observation*). Burrowing Owls frequently consume small amounts of grass and plant fragments, potentially to aid in the formation of regurgitated castings (MacCracken et al. 1985).

Foraging Behavior

Burrowing Owls hunt in open areas with bare ground, roadside ditches and right-of-ways with tall vegetation, wetlands, uncultivated fields, as well as cultivated fields (Thomsen 1971, Green 1983, Haug 1985, Haug and Oliphant 1990, Haug et al. 1993). In Wyoming and elsewhere, peak foraging occurs at sunrise and sunset; nocturnal foraging for small mammals and mid-day foraging for invertebrates are common habits (Thompson and Anderson 1988, Martin 1973, Haug et al. 1993). During the early breeding season while females are incubating, males do most of the hunting (71% in Wyoming) (Thompson and Anderson 1988). Burrowing Owls hunt by 4 primary hunting strategies: ground foraging (running, hopping, chasing prey on foot), observational foraging (sit-and-wait hunting from perch), hovering, and flycatching (Thomsen 1971, Thompson and Anderson 1988). Ground foraging is the primary mode of hunting, occurring at the highest frequency during mid-day (presumably during peak activity for ground-dwelling insects such as grasshoppers and beetles) (Thompson and Anderson 1988). Prey is captured with the talons and crushed with the bill, and delivered from the bill to the female and owlets (Haug et al. 1993).

There do appear to be seasonal shifts in Burrowing Owl diet. In the early breeding season, males take mostly small mammals and small birds (Martin 1973, Thompson and Anderson 1988, Haug et al. 1993). As time during breeding season advances, the frequency of vertebrates taken decreases and percentage of invertebrates taken increases (Martin 1973, MacCracken et al. 1985, Thompson and Anderson 1988, Green and Anthony 1989, Haug et al. 1993).

Community Ecology

Predation may be an important limiting factor for Burrowing Owls because they are small and spend most of their life on the ground (nesting, hunting, roosting) (McDonald et al. *in press*). Primary predators of Burrowing Owls include badgers (*Taxidea taxus*), coyotes (*Canis latrans*), fox (*Vulpes* spp.), Great-horned Owls (*Bubo virginianus*), Red-tailed Hawks (*Buteo jamaicensis*), and Swainson's Hawks (*Buteo swainsoni*), with occasional predation by other mesopredators and raptors (Haug et al. 1993). Badgers are major predators of Burrowing Owls, responsible for 90% of depredation in Oregon (Green 1983). Pressure from predators can be severe in reintroduction areas (Leupin and Low 2001), as well in areas where habitat fragmentation has increased movement pathways for common and novel predators (e.g. raccoons (*Procyon lotor*) become more common when amount of edge increases; see Crooks and Soule 1999) (Warnock and James 1997, Clayton and Schmutz 1999). Wellicome et al. (1997) found that Burrowing Owl nest burrows with predator exclusion devices had significantly higher nest success than natural, unprotected burrows in Canada. In urban landscapes, predation from domestic cats can be responsible for high percentages of mortality in Burrowing Owls (Millsap and Bear 1988), and dogs have been observed feeding on eggs and young (Haug 1985).

Burrowing Owls select nests in close proximity to each other, showing patterns of clustering and loose coloniality (Desmond et al. 1995). As such, intraspecific competition does not appear to be a factor in Burrowing Owl community ecology. While Burrowing Owls have a wide dietary breadth and likely take the same prey items as other predatory animals, there are no published studies showing direct interspecific competition for food resources. Nor are there studies showing direct interspecific competition for other resources, such as nest burrows; Burrowing Owls are usually capable of evicting burrowing mammals from burrows and maintaining those burrows throughout the breeding season (McDonald et al. *in press*).

Burrowing Owls appear to have a commensalistic interaction with prairie dogs. While prairie dogs appear unaffected by the presence of Burrowing Owls, they may confer a host of benefits for the owls (although few have been quantified). As described in the *Breeding Microhabitat* section, owls will preferentially nest in prairie dog colonies with higher burrow availability relative to the surrounding landscape. Moreover, Burrowing Owls will preferentially nest within active prairie dog colonies (Desmond et al. 2000, Restani et al. 2001, McDonald et al. *in press*). Prairie dogs maintain integrity of burrows that may become available to the owls, and clip vegetation around burrows - thereby improving visibility of predators and prey. Burrowing Owls may also benefit by responding to the predator-alarm vocalizations that prairie dogs use for members of their own coteries, but such behavioral responses have not been quantified.

Conservation

Conservation Status

The Burrowing Owl is a neotropical migrant that receives protection under the Migratory Bird Treaty Act (1918) and the Convention of International Trade in Endangered Species (CITES; http://www.natureserve.org/explorer). In 1972, the Burrowing Owl was included on the Audubon Blue List, intended to provide an early warning about avian population decline and/or range contraction (Tate 1986). In the United States, the Burrowing Owl has been listed as vulnerable (US Department of Interior 1991), sensitive (US Department of Interior 1992), a federal Category 2 candidate species for listing on the Endangered Species Act, and a bird of conservation concern

(US Fish and Wildlife Service 2001). The US Fish and Wildlife Service officially dropped the Category 2 designation for the Burrowing Owl in 1996, but it remains a National Bird of Conservation Concern (Office of Migratory Bird Management 1995). The Burrowing Owl is given conservation status in US Fish and Wildlife Service Regions 1 (Pacific Region, mainland only), 2 (southwest region), and 6 (mountain-prairie region) (Klute et al. 2003). The Burrowing Owl is also listed with regional conservation priority (Tier II, http://www.rmbo.org/pif/jsp/BCRbmap.jsp) in 9 NABCI Bird Conservation Regions throughout mid- and western United States (Klute et al. 2003). (NABCI – North American Bird Conservation Initiative, is a coalition of government agencies, private organizations, academic and industrial institutions concerned with bird conservation, http://www.abcbirds.org/nabci/index.htm). The US Fish and Wildlife Service does not list Burrowing Owls federally as threatened or endangered, and no federal petitions have been made (http://endangered.fws.gov/wildlife.html). Burrowing Owls are listed as endangered in Canada, and receive protection in the provinces of British Columbia, Alberta, Saskatchewan, and Manitoba. Despite a presumably wide distribution in Mexico, the lack of quantified information on status prompted listing of the Burrowing Owl as threatened (amenazada) in 1994 (Holroyd et al. 2001).

NatureServe, an international organization that networks national and state heritage programs, ranks the Burrowing Owl with a Global Heritage Status of G4 – meaning that the species is apparently secure but may be rare in the periphery of its range (http://natureserve.org/explorer). The Global Heritage Trinomial rank (rangewide status of *A.c. hypugaea*) is TU, meaning the western subspecies is possibly in peril but status is uncertain. Several regional state heritage programs list the Burrowing Owl as S3, meaning they are rare or local throughout their range, or found locally in a restricted range: Wyoming (http://uwadmnweb.uwyo.edu/wyndd/), Nebraska (http://www.natureserve.org), Kansas (http://www.kbs.ukans.edu/), and South Dakota (http://www.state.sd.uw/gfp/Diversity/). Colorado ranks Burrowing owls as S4 (apparently secure but rare at periphery of range, http://www.cnhp.colostate.edu/index.html). Wyoming Natural Diversity Database (WYNDD) gives the Burrowing Owl a low conservation ranking because Wyoming is in the medium portion of the range, continental distribution is wide, but status in Wyoming is uncertain relative to other areas (Table 5; http://uwadmnweb.uwyo.edu/wyndd/Animals/Birds/Owls/owls.htm).

A summary of these various heritage ranks suggests that Burrowing Owls are considered rare or locally restricted with uncertain status. As such, many US state wildlife agencies have listed the Burrowing Owl as a Species of Special Concern. Within the mountain-prairie region, 'special concern' designation is given to Burrowing Owls in Wyoming, South Dakota, Kansas, and Nebraska (Sheffield 1997). The Colorado Division of Wildlife lists the Burrowing Owl as threatened (VerCauteren 2001).

The Wyoming Game and Fish Department (Luce et al. 1999) considers the Burrowing Owl a species of concern because of a wide distribution throughout out the state but little information on status and population trend. The Wyoming Partners in Flight state conservation plan lists Burrowing Owls as a Level I species, requiring immediate conservation action (Nicholoff 2003).

Biological Conservation Issues

Abundance and Population Trends

To properly assess abundance and population trends for Burrowing Owls at a range-wide scale, standardized surveys are needed for application throughout North America. While standardized methods have been developed and tested for bias and detection probabilities (Appendix I; Conway and Simon 2003), these methods have not been applied on a continental scale. As a result, abundance estimates vary among populations not just because actual numbers vary, but also because survey and abundance-estimation methods vary.

In a questionnaire distributed to 24 wildlife agencies within the breeding range of the Burrowing Owl, James and Espie (1997) assessed status in North America. Respondents were asked 1) to estimate, to the nearest order of magnitude (1-10 pairs, 10-100 pairs, 100-1000 pairs, etc.) the breeding population within their agency jurisdiction, 2) to assess if the population was stable, increasing, or decreasing, 3) to determine the limiting factors for the population, and 4) to report the status of the population (Table 2). Fifty-four percent (13 of 24) of the agencies reported that their Burrowing Owl populations were declining, and none of the respondents reported an increasing population (James and Espie 1997). Within Wyoming, Burrowing Owls were reported to have a low population size (1000-10000 pairs), stable population, habitat loss as the limiting factor, and status of special concern. Overall survey results suggested that Burrowing Owls were still numerous within North America, but that population trend showed decline throughout the range. The authors noted that while agency questionnaires are informative when logistics prohibit extensive field surveys, these results were not based on accurate count data (James and Espie 1997).

The Breeding Bird Survey (BBS) results show considerable variation in population trends across the range (Sauer et al. 2002). Note: BBS trends are not entirely reliable as they are limited by small sample sizes and inadequate sampling regimes, and trends in most regions are limited by important or potential data deficiencies (Klute et al. 2003). However, the results do indicate general declining populations in the northern Great Plains, with declines also present in more specific regions such as the Wyoming basin, and the state of Wyoming (Table 3; Sauer et al. 2002).

In 1999 and 2000, the Rocky Mountain Bird Observatory (RMBO) conducted roadside surveys within potential habitat in southeastern Wyoming (Platte, Goshen, Laramie, and the extreme southern Niobrara counties). In 1999, RMBO located 180 individual owls at 71 sites; in 2000, RMBO located 575 individual owls in 107 sites (Hutchings et al. 1999). Site reoccupancy was 66% from 1999 to 2000 (Klute et al. 2003).

In 1999, Korfanta et al. (2001) surveyed 103 historic Burrowing Owl locations as well as 85 randomly-selected sites within potential habitat. Surveyors found 37 individual owls at 16 sites (36 at historic, WOS locations; 1 at a randomly-selected site). Korfanta et al. (2001) also examined Burrowing Owl sightings (1974-1997) in the Wyoming Game and Fish Department Observation System (WOS). Burrowing Owl sightings were broadly distributed, with highest concentrations in southern Wyoming (Figure 7). Numbers of sightings increased between 1974-1980, while records decreased between 1981-1997 (significant, negative linear relationship p=0.002; Figure 10). While the negative relationship between Burrowing Owl sightings and time from 1981-1997 was significant, Korfanta et al. (2001) question the reliability of the WOS, as reporting bias may affect actual population trends.

Standardized roadside surveys (Appendix I) were conducted in black-tailed prairie dog colonies within the Thunder Basin National Grasslands in 2001-2003 (Conway and Hughes 2001, Conway and Lantz 2002, 2003). In 2001, 67 prairie dog colonies were surveyed and 70 adult Burrowing Owl were detected (Table 4). In 2002, 73 prairie dog colonies were surveyed and 106 adult owls were detected. In 2003, 73 prairie dog colonies were surveyed and 139 adult owls were detected. Apparent increases in colonies surveyed and owls detected from 2001 to 2002 are influenced by increased observer effort; only 1 observer was used in 2001 while 2 observers were used in 2002 and 2003, likely increasing detection probability. Occupancy rates of prairie dog colonies varied from 24-40%, and re-use of prairie dog colonies by Burrowing Owls were 57% (2002) and 38% (2003). Overall rate of colony re-use from 2001-2003 was 38%. These occupancy rates (24-40%) can be compared to those of Sidle et al. (2001), who estimated 16% of prairie dog colonies within Thunder Basin National Grasslands were occupied by Burrowing Owls in 1998. The higher occupancy rates in 2001-2003 relative to those in 1998 are likely due to survey method: in 1998, Sidle et al. (2001) located owls through visual observation from vantage points, spending between 20-60min. in each colony. Efficacy of this method was not measured, and may suffer from greater variability in observer effort and sighting probability than a standardized method as in Appendix I.

Range Contraction

In the last 30 years, several states and provinces have reported absences of Burrowing Owl populations where they were formerly common (Wellicome and Holroyd 2001). Alberta, Saskatchewan, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, Washington, and California have all reported retreating distributions (Figure 5; Wellicome and Holroyd 2001). Burrowing Owls have been extirpated from the Canadian provinces of British Columbia and Manitoba, and in the United States populations in Minnesota have been extirpated.

Population-trend surveys in southern Alberta show that nest density ($\bar{x} = 13.7$ nests per $100km^2$) declined significantly from 1991-2000 (Shyry et al. 2001). In 1991, surveys near Hanna, Alberta found 32.6 nests/$100km^2$. In 1997, the same surveys found only 2.8 nests/$100km^2$, with a significant negative trend in nest density over time ($p<0.01$) (Shyry et al. 2001). Factors influencing the decline were not clear to the authors, as the area of mixed-grass prairie had not notably decreased during the years of the survey. Suggested factors influencing decline were environmental (e.g. precipitation, prey abundance, predator abundance), metapopulation dynamics (e.g. dispersal, immigration, emigration), and/or continental declines causing the range to collapse toward its core (these surveys were within the periphery of Burrowing Owl distribution).

In northwestern North Dakota, surveyors were able to detect Burrowing Owls at 3% of historical nest areas (Murphy et al. 2001). Available grassland habitat and associated burrowing mammals declined at an average of 33% since the 1960s, with losses attributed to agricultural conversion to cropland. In Minnesota in the early 1920s, Burrowing Owls were considered common in most of the western counties (Martell et al. 2001). By the mid-1960's only 9-10 breeding pairs were known, with a statewide estimate of 20 pairs. From 1965-1985, 20 pairs were documented within west-central Minnesota, and no successful breeding pairs were documented from 1992-1998 (Martell et al. 2001). Drastic population decline in Minnesota was attributed to 3 factors: intense cultivation, plowing of prairie and pastureland, and decimation of burrowing mammals. Saskatchewan reported a 95% decline in the number of breeding pairs occupying lands protected for Burrowing Owls, from 1998 [1032 pairs] to 2000 [56 pairs] (Operation Burrowing Owl lands, Skeel et al. 2001). Rapid losses in Saskatchewan were the end-result of a century of agricultural conversion, loss of burrowing mammals, habitat fragmentation, pesticide use, and reduction in prey availability (Skeel et al. 2001). Much the same, urban and agricultural development, incompatible grazing practices, and eradication of fossorial mammals were responsible for the extirpation of Burrowing Owls from British Columbia by 1980 (Leupin and Low 2001).

Habitat loss to urban, resource, and agricultural development is cited as the primary reason for the decline of Burrowing Owls throughout their range (Table 1; James and Espie 1997). In Wyoming, losses of burrowing mammals, encroachment of sagebrush into formerly short- and mixed-grass prairie areas, and increasing landscape conversion for resource development are forms of Burrowing Owl habitat loss, and can be considered as factors potentially responsible for apparent declines in sightings throughout the state (Table 1; Korfanta et al. 2001, McDonald et al. *in press*). While Wyoming represents part of the still-intact core of the Burrowing Owl distribution, the factors causing contraction at range's extremities are the same factors at work within Wyoming. As such, pro-active management and conservation of Burrowing Owl habitat in Wyoming may help to prevent further shrinking and decline.

Intrinsic Vulnerability

Attributes characteristic of an intrinsically vulnerable population include: small size, genetic isolation, low dispersal rates, endemism, habitat specificity, high hybridization potential, and low fecundity. The small size of populations remaining at the edge of the range may be intrinsically vulnerable to perturbation, but overall Burrowing Owls do not show many of the characters listed above. Korfanta (2001) has shown that there is no genetic isolation among populations of the western subspecies, and that long-distance dispersal events are likely. Variability among landscape and habitat use among populations across the range indicate that Burrowing Owls do not have extremely specific habitat requirements, and that some change in land use is accommodated. However, there are 3 attributes of Burrowing Owl ecology that may endanger populations when disturbed.

1. Productivity will fluctuate with prey availability. Clutch sizes can be larger when more prey is available (Haley 2001), and the number of young fledged can increase by as much as 40% when prey is abundant (Wellicome et al. 1997). Post-fledging survival is significantly higher in years of high prey abundance, and populations will fluctuate as a result (Todd et al. 2003). Years of low precipitation, loss of vegetal cover via habitat conversion, pesticide, and rodenticide use may reduce abundance of natural prey, which can lower Burrowing Owl productivity rates.

2. Many populations of Burrowing Owls are migratory, therefore annually exposed to energetic stress and environmental factors that may impact survival. Land use changes along migratory pathways may decrease food and cover resources, increasing predation and exhaustion risks. So little is known about factors influencing survival on the wintering grounds (Holroyd et al. 2001), and it may be possible that poor winter habitat quality increases vulnerability for migratory populations.
3. Variability among landscape types used by Burrowing Owls (from suburbia to native prairie) suggests some degree of flexibility in habitat requirements. However, owls require multiple burrows for nesting and satellite use. The availability of burrows is the limiting factor in Burrowing Owl habitat, and the apparent preference to nest within active colonies of burrowing mammals shows some degree of specificity. Burrow losses can negatively influence nesting density, fledge rates, and juvenile survival (Butts and Lewis 1982, Desmond et al. 2000, Restani et al. 2001).

Extrinsic Threats

Habitat Loss and Fragmentation

The information presented below pertains to habitat losses on the breeding grounds. Documentation and research pertaining to Burrowing Owl wintering habitats is limited and largely speculative (Holroyd et al. 2001).

Samson and Knopf (1994) estimate the area of intact, mixed-grass and shortgrass prairie has declined between 20% (Wyoming) and 99.9% (Manitoba). As a result, grassland birds have declined precipitously (an estimated 24-91% decline from 1979-1991), more than any other avian guild breeding in North America (Samson and Knopf 1994). Burrowing Owls are among declining grassland birds, and habitat loss has been identified as the single most important threat to persistence (Haug et al. 1993, James and Espie 1997, Sheffield 1997, Klute et al. 2003, McDonald et al. *in press*). Primary forms of habitat loss affecting Burrowing Owls include urban, industrial, and agricultural conversion of native prairie, losses of burrowing mammals, and fragmentation. While urbanization may not currently be a factor in Wyoming, industrial and agricultural development are burgeoning state industries that may result in fragmentation and/or loss of Burrowing Owls habitat.

The effect of agricultural development on Burrowing Owl habitat depends on type and intensity. Intense agricultural practices (such as monoculture crops and trench irrigation) require plowing and digging, which can result in burrow loss and increased vegetation density and height. This type of conversion is responsible for losses of many Burrowing Owl populations in Manitoba, Minnesota, British Columbia, and Saskatchewan (Clayton and Schmutz 1999, Holroyd and Wellicome 2001, Shyry et al. 2001, Martell et al. 2001, Leupin and Low 2001). As a less intense form of agriculture, livestock production has the potential to enhance Burrowing Owl habitat in the absence of other grazing herbivores (such as bison) (Kantrud and Kologiski 1982, MacCracken et al. 1985). However, the benefit of rangelands to Burrowing Owls must be considered in conjunction with the presence of burrows (hence, burrowing mammals) (Klute et al. 2003). Range management practices that promote wide-scale eradication programs for prairie dogs and ground squirrels will result in the eventual loss of burrows, thus loss of Burrowing Owl habitat.

Burrowing Owls are inextricably linked to burrowing mammals, and much of the decline in abundance and subsequent range contraction of Burrowing Owls is linked to the decline of burrowing mammals. Declines in burrowing mammals are due to land conversion for agriculture or urban development, large-scale removal efforts (poisoning and shooting), and the sylvatic plague (*Yersinia pestis*) (Miller et al. 1994, Antolin et al. 2002). In 1900 there were an estimated 40,000,000ha of prairie dog habitat. In 1960 that number had been reduced to 600,000ha, a 98.5% decline in habitat within 60 years (Miller et al. 1994). In Wyoming, Burrowing Owl presence is linked to the presence of prairie dogs (Korfanta et al. 2001, Conway and Lantz 2002). However, prairie dog colony activity in Wyoming is declining: active prairie dog colony area within the Thunder Basin National Grasslands has declined by 89% since 2001 (losses due to plague epidemic) (Byer 2001).

The rapid loss of grasslands in North America is responsible for making the Great Plains one of the most heavily fragmented landscapes in the world. By definition, fragmentation converts large, contiguous tracts of wildlife habitat into small, isolated patches (Noss and Csuti 1994). Fragmentation of Burrowing Owl habitat may increase 1) distances to foraging habitat, 2) density of owls on patches with concomitant increases in intraspecific competition, and 3) mortality due to edge effects (Warnock and James 1997). Fragmentation may also facilitate predator influx and decrease distribution and abundance of prey.

Increased development tends to increase the density of roads, and in certain areas, automobiles constitute a significant source of mortality for Burrowing Owls (Haug et al. 1993, James and Espie 1997, McDonald et al. *in press*). Burrowing Owls can have higher juvenile mortality from vehicle collisions in an agricultural landscape (>90% of land area under cultivation) relative to an unfragmented rangeland (<20% cultivation) (Clayton and Schmutz 1997). Todd and James (2001) found that 7% of post-fledging mortality was due to vehicular collisions, relative to 60% by avian predators. Within the urban and agricultural landscapes of eastern Washington, Conway and Ellis (*unpublished data*) documented 17% adult- and 29% juvenile mortality due to vehicular collisions in 2003.

Depredation

Land use practices that fragment landscapes or shift habitat types into early successional stages have increased habitats for predators such as coyotes, red fox (*V. vulpes*), grey fox (*Urocyon cinereoargenteus*), and badgers. Elevated rates of depredation on Burrowing Owls have been documented within fragmented and modified landscapes (Clayton and Schmutz 1999, Warnock and James 1997). In urban areas, depredation from domestic dogs and cats can severely impact nest success (Millsap and Bear 1988).

Burrowing Owl reintroduction efforts in Minnesota and British Columbia have been largely unsuccessful due to high depredation rates of released individuals (Leupin and Low 2001, Martell et al. 2001). In British Columbia, 92% of known mortalities of released individuals were the result of predation (Leupin and Low 2001). In Saskatchewan, fledge rates from artificial nest burrows were higher when predator exclusion devices were present (Wellicome et al. 1997).

Pesticides

The use of insecticides and rodenticides within Burrowing Owl habitat can be detrimental. Direct poisoning or secondary ingestion of pesticide-laden prey will cause mortality (James and Espie 1997, LeClerc 1990, Baril 1993, World Wildlife Fund 1993, Blus 1996, Sheffield 1997, Gervais et al. 2000). Rodent control treatments such as strychnine-coated grains and fumigation have been shown to cause direct mortality in Burrowing Owls, and to decrease adult body mass and breeding success (Klute et al. 2003). Insecticides such as carbofuran and carbaryl will reduce brood production by as much as 83% when applied directly to nest burrows (James and Fox 1987). Whether accumulation occurs primarily on the breeding or wintering grounds is largely unknown. However, application of these pesticides is legal within the United States and may be used in croplands and prairie dog colonies within Wyoming.

Incidental Shooting

One incidental shooting of a Burrowing Owl within a recreationally-hunted prairie dog colony was found and reported in 2004 within the Thunder Basin National Grasslands, Wyoming (Lantz *personal observation*). While largely unreported, incidental shooting of Burrowing Owls within recreationally-hunted prairie dog colonies may be an important, overlooked threat (James and

Espie 1997). For instance, in one Oklahoma population, shooting accounted for 66% of total adult mortality (Butts 1973). In Canada, three Burrowing Owl populations were entirely decimated by shooting (Wedgewood 1976). Recreational shooting of prairie dogs may also have indirect effects of stress on individual owls. Woodard (2002) found that nest success rates and number of young fledged by owls in prairie dog colonies subject to recreational shooting (fledge rate = 1.2, N=39 nests) were significantly lower than in colonies where shooting of prairie dogs did not occur (fledge rate = 1.8, N = 58 nests).

A Wyoming study in 2002 examined if and how much Burrowing Owls (and other raptors) were ingesting lead from scavenging shot prairie dogs (Stephens et al. 2003). Scavenging observations were made within shot prairie dog colonies, metal contents within prairie dog carcasses were analyzed, and blood/feather samples were bioassayed for lead concentrations for several species of raptors. Pin feathers were collected from 43 Burrowing Owls (20 from shot colonies [7 juvenile/13 adult] and 23 from unshot colonies [11 adult/12 juvenile]). Burrowing Owls were not detected scavenging prairie dogs within recreationally-shot colonies, and lead concentration within feathers was below sub-clinical levels.

Indirect Effects of Sylvatic Plague

While there are no known diseases that directly threaten Burrowing Owl populations, losses of prairie dogs to the sylvatic plague may threaten Burrowing Owl habitat. Plague is the only source of mortality known to cause >95% die-offs in black-tailed prairie dogs (Barnes 1993, Cully and Williams 2001). Plague is responsible for an 89% decline in active colony area within the Thunder Basin National Grasslands in Wyoming (Byer 2001). While the pattern of plague movement across the landscape and its mode of transmission are not well-understood, its influence may cascade to other taxa associated with active prairie dog colonies, such as the Burrowing Owl (Antolin et al. 2002). A 14-year study on the Rocky Mountain Arsenal National Wildlife Refuge

(RMANWR) in Colorado documented the number of nesting Burrowing Owls as it related to prairie dog population size and colony area (Lutz and Plumpton, as cited in Antolin et al. 2002). Prairie dog colonies within the RMANWR were hit by several plague epizootics during the study, driving prairie dog populations up and down over time. As a result, active colony area fluctuated, and Burrowing Owl nesting density tracked these fluctuations (Figure 11).

Protected Areas

At this time, there are no areas within Wyoming designated specifically for protection of Burrowing Owls. Land ownership within Burrowing Owl habitat is primarily private. Land ownership within grassland habitat-types occupied by Burrowing Owls is a mix of private, US Bureau of Land Managment, and US Forest Service lands. Land ownership within shrub-steppe habitat-types is both public (US Bureau of Land Management) and private. Burrowing owls have been observed at Hutton Lake and Mortenson Lake National Wildlife Refuges (US Fish and Wildlife Service) (Lantz *personal observation*). The Burrowing Owl is included as a high priority species within the Cellars Loop Important Bird Area (IBA) designated by Audubon (A. Lyon, *personal communication*), contained within the Thunder Basin National Grasslands in northeastern Wyoming. An IBA provides essential habitat, monitors status, and elevates the conservation status of an area for birds of high conservation priority.

Conservation Action

Existing or future conservation plans

The Burrowing Owl is not federally protected as Threatened or Endangered, so an official recovery plan is not enforced. However, the US Fish and Wildlife Service has developed a conservation plan for Western Burrowing Owls, listed below (Klute et al. 2003). Wyoming

Partners in Flight has also developed a conservation plan (Nicholoff 2003), and regional management directives are included below.

The Migratory Bird Management program of the US Fish and Wildlife Service recommends retaining the Burrowing Owl on the Bird of Conservation Concern list on which it currently appears (Klute et al. 2003). This designation highlights potential vulnerability and promotes collaborative, proactive conservation actions among agencies and the public. As such, the US Fish and Wildlife Service has developed the following conservation plan and management recommendations for Burrowing Owls in the west (paraphrased from Klute et al. 2003). These recommendations, while derived from multiple consultations and sources, are largely based on the conservation action-items developed by researchers and experts at the second international Burrowing Owl symposium at the Raptor Research Foundation conference in Ogden, Utah in 1998 (Holroyd et al. 2001).

1. Monitor demographics and population trends more precisely. Standardized, roadside surveys should be tested for quantitative validity and implemented range-wide (see Appendix I, and Conway and Simon 2003). Historical sites and areas previously unoccupied by Burrowing Owls should be monitored. Range-wide population trends should be compared using data collected with standardized methods.
2. Conservation efforts should focus on protection of suitable habitats in grasslands, shrub-steppe, and desert environments. Habitat management should enhance productivity and survival of the owls, and their prey. Standardized mitigation protocols to minimize impacts from development should be implemented. Management of public lands should consider habitat requirements for Burrowing Owls and the associated fossorial mammals.
3. Additional effort should focus on determining status of Burrowing Owl in Mexico, and reversing decline and extirpation in the northern Great Plains and Canada. Research is needed on habitat use in wintering areas, as well as the ecology and timing of migration during the winter.

4. Burrowing mammals must be conserved, and the listing of the black-tailed prairie dog as a Candidate species should help to protect both prairie dogs and Burrowing Owls. Development of economic incentives to maintain prairie dog populations on private lands may be necessary. Regulation of poisoning and shooting of prairie dogs is necessary. If lethal control is inevitable, control activities should be restricted to avoid the Burrowing Owl nesting period.
5. A review of existing reintroduction techniques is necessary. Reintroduction programs in British Columbia, Manitoba, Minnesota, and Oklahoma have been largely unsuccessful, and the efficacy of reintroduction should be evaluated. Limiting factors such as prey availability and habitat quality should be evaluated prior to reintroduction.
6. The rates of survival and reproduction of Burrowing Owls relocated to artificial burrows need to be determined. While owls will use artificial burrows and successfully rear young from artificial burrows, the ability of these burrows to maintain populations in the long term is unknown. Design and installation techniques should be summarized for distribution to managers.
7. Pesticide use should not negatively affect Burrowing Owls. If insecticide use is necessary, chemicals with the lowest toxicity to non-target species are recommended. Application of insecticides should not occur within 600m of known Burrowing Owl nests. Rodenticide use, when necessary, should be restricted to the non-breeding season.
8. Public education about the status of Burrowing Owls, and the importance of protecting Burrowing Owl and prairie dog habitat should be stressed. Stewardship with regard to Burrowing Owl habitat should be promoted to private landowners, and landowner cooperation programs (such as Operation Burrowing Owl in Canada, see Hjertaas 1997) should be developed.

In the Wyoming Partners in Flight (WY-PIF) “Wyoming Bird Conservation Plan” (Nicholoff 2003), Burrowing Owls are designated a Level I species, meaning that immediate conservation action and monitoring are necessary. WY-PIF recommends two population objectives: 1. Determine statewide population trends using “Monitoring Wyoming’s Birds: The Plan for Count-based Monitoring” developed by Leukering et al. 2001, and 2. Maintain the 22 existing Breeding

Bird Survey routes at which Burrowing Owls have been detected within Wyoming, and maintain annual detection rates along those routes.

Conservation Elements

Management Recommendations

The conservation elements of Burrowing Owl management in Wyoming include: habitat enhancement and conservation, conservation of prairie dog populations, stabilization of prey populations and prey habitats, continued research, public education, and private landowner/land manager cooperation. While captive breeding and reintroduction are mentioned in Klute et al. (2003), such efforts are not necessary within Wyoming where Burrowing Owls are still present. The following management recommendations listed for each conservation element are largely adapted from the WY-PIF "Wyoming Bird Conservation Plan" (Nicholoff 2003), "Effects of management practices on grassland birds: Burrowing Owl" (Dechant et al. 1999), and "Sharing your land with shortgrass prairie birds" (Gillihan et al. 2001), Holroyd et al. (2001), and Klute et al. (2003).

Habitat Enhancement and Conservation

1. Maintain prairie dog colonies via landowner agreements and habitat management plans.
2. Designate ¼-mile to ½-mile buffer zones around known Burrowing Owl nests where pesticide use, rodent control, and human disturbances are restricted.
3. Protect all known nest burrows, and retain prairie dog burrows as future nest burrows.
4. Maintain areas of short grass and open ground.
5. Do not eliminate prairie dogs and ground squirrels.
6. Avoid fragmenting habitat in known nesting areas. Roads, pipelines, plowing, and industrial developments will fragment Burrowing Owl habitat and should be avoided in known nesting areas.

7. Delay spring mowing in hayfields until late July (when most nests have fledged young), avoid nighttime mowing, and space mowings widely apart throughout the hay season to allow higher likelihood of successful nesting.
8. Leave dirt berms along edges of cultivated fields.
9. Consider installing artificial nest burrows in areas were burrowing mammals have been exterminated and burrow availability has diminished.
10. Preserve rights-of-way, haylands, and uncultivated fields within 600m of nests for foraging. Taller grasses may be grazed to attract primary burrows such as prairie dogs.
11. Provide fresh cattle dung near nesting areas if dung is not available.

Prairie Dog Conservation

Conservation of burrowing mammals that form Burrowing Owl nest burrows is absolutely essential (Klute et al. 2003). As described in the *Habitat Loss and Fragmentation* section, prairie dog populations are declining and fragmentation has isolated some colonies so that re-colonization via natural dispersal is unlikely. Without active maintenance by prairie dogs, burrows can collapse become overgrown with vegetation within 1-2 years and are no longer suitable for nesting Burrowing Owls. Additional research on sylvatic plague is needed and methods for prairie dog vaccination against plague should be considered. Eradication campaigns such as shooting and poisoning should be restricted within known Burrowing Owl areas. It may be necessary to release prairie dogs into inactive colonies, provided plague is not still present within the burrows of the colony (Klute et al. 2003). Economic incentives should be developed and provided to private landowners to make the maintenance of prairie dog populations profitable, and land managers should consider the expansion of prairie dog colony area on public lands to increase available habitat for Burrowing Owls.

Prey Abundance and Habitat Conservation

Avoid controlling small rodents and insects (primarily grasshoppers, crickets, and beetles) within ¼ to ½ mile of known Burrowing Owl nest sites. If the use of insecticide is necessary, restrict application until after mid-July (after most nests have fledged). Maintenance of small areas of tall vegetation within 250m Burrowing Owl nest sites will help to retain habitat for small rodents.

Continued Research

Wyoming needs to make a concerted effort to collaborate with other states and provinces conducting research on Burrowing Owl populations to ensure coordinated, standardized research on population demographics and distribution. The following research action items include recommendations from Holroyd et al. (2001) and Klute et al. (2003):

1. Study population demographics to help determine causes of decline (see Conway and Hughes 2001, Conway and Lantz 2002 and 2003 for current demographic study).
2. Use standardized surveys to achieve accurate, statewide distributional information, and maintain annual surveys to monitor changes in distribution over time.
3. Determine annual site fidelity.
4. Determine the effect of predation (natural and feral predators) and other sources of mortality on Burrowing Owl populations.
5. Develop models of Burrowing Owl habitat use within Wyoming, including the role of human activity.
6. Evaluate the effects of pesticides on Burrowing Owls in Wyoming, where applicable.
7. Evaluate the effects of industrial development on Burrowing Owl habitat, movement, and behavior.
8. Determine how prairie dog population losses due to sylvatic plague influence Burrowing Owl nest distribution and abundance in Wyoming

9. Since owl populations in Wyoming are migratory (Conway and Lantz 2002), consider techniques and research to determine migratory timing, pathways, and wintering destinations.
10. Evaluate current management strategies for their effectiveness and whether the resulting information is available to managers.

Public Education and Cooperation

1. Educate the public and the private landowners about Burrowing Owl status and conservation. Increase awareness of Burrowing Owl habitat.
2. Enlist private landowners to help protect existing Burrowing Owl habitat. In Canada, Operation Burrowing Owl (OBO) is a stewardship program that protects known nesting locations via volunteer contract. Landowners agree not cultivate a defined nesting area for a five-year term and to report numbers of nesting pairs to OBO personnel. In return, landowners received an OBO sign to be places at the entrances to their land, as well as a Burrowing Owl newsletter. From 1987 to 1992, 499 landowners enrolled 16,000ha of land into the program, and over 85% of landowners contacted participated (Hjertaas 1997).
3. Educate recreational prairie dog shooters on Burrowing Owl identification to avoid incidental shooting of owls perched at burrow entrances.
4. Use the Burrowing Owl as a flagship species to promote prairie conservation.
5. Develop educational materials for school curricula and use non-releasable Burrowing owls and captive-bred owls for education purposes.
6. Develop educational brochures with identification information and simple habitat management tools for distribution to private landowners (see Gillihan et al. 2001).
7. Promote conservation of grasslands and Burrowing Owls through television, newspapers, magazines, the Internet, and other forms of media.

In addition to the educational booklet “Sharing Your Land with Shortgrass Prairie Birds” (Gillihan et al. 2001), RMBO manages “Prairie Partners” (Hutchings et al. 1999). “Prairie Partners” is a program that gathers volunteer cooperation from private landowners for conservation of prairie birds and their habitats. In 1999, RMBO collected 468 Burrowing Owl locations via reported sightings on public and private lands. Through the “Prairie Partners” program, RMBO provides landowners with information about shortgrass prairie conservation and Burrowing Owl natural history. Wildlife agency personnel, university researchers, and land managers who are in direct contact with private landowners and the public should consider promoting “Prairie Partners” and other landowner cooperation programs like OBO.

Inventory and Monitoring

In order to adequately measure population trend, surveys must be conducted to locate and monitor populations, and a standardized protocol is required for results to be comparable among populations. Roadside surveys have been used extensively for Burrowing Owls (Conway and Simon 2003, Coulombe 1971, Wedgewood 1976, VerCauteren et al. 2001). Conway and Simon (2003) recently developed a standardized roadside point-count survey method, tested in Wyoming, Washington, and Arizona (Appendix I). When tested against two other survey methods: line-transect and driving surveys, roadside point-count surveys had a higher detection probability (64%) than the other two survey methods (line transects were largely ineffective and driving surveys had a detection probability of 37%). When the male territorial call (*coo-coooo*; Haug and Didiuk 1993) was broadcasted at each survey point, detection rates increased by 22%. When roadside surveys were conducted in triplicate over the course of the breeding season, the probability of detecting all the Burrowing Owls within the sampled area was high (95%). Standardized point-counts using call-broadcast along roadsides provide the most effective means of monitoring population trend over large spatial scales.

Annual site fidelity can be measured with annual burrow monitoring programs (Conway and Hughes 2001, Conway and Lantz 2002, Conway and Lantz 2003). Historical sites, nesting sites identified with roadside surveys, and previously unoccupied burrows within high-quality habitat can be monitored to determine rates of use and re-use by Burrowing Owls. Monitoring owl-occupied burrows seasonally can also provide measures of annual fecundity (see section on *Reproductive Success*). Monitoring Burrowing Owl nest sites every 3-4 days throughout the breeding season allows for use of robust nest success estimators with reduced biases associated with unknown nest fates. To avoid over-disturbance of nesting owls, nests should only be approached every other visit, with most visits consisting of distant observation (50-150m) using spotting scopes and binoculars. Infrared burrow videoscopes allow for accurate counts of clutch size, number of young hatched, as well as assessment of occupancy (Conway and Lantz 2002, Conway and Lantz 2003).

Annual adult and juvenile survival, philopatry, and juvenile recruitment can be measured using mark-recapture methods such as those in use in the Thunder Basin National Grasslands of Wyoming (Conway and Lantz 2002, Conway and Lantz 2003). Burrowing Owls are banded with aluminum alpha-numeric color bands and USFWS non-locking No. 4 bands. Attempts to mark and resight a large segment of the population are made annually. Owls are captured using spring-net traps baited with a caged mouse, and two-way burrow traps (Botelho and Arrowood 1995). Resights are made by distant observations (50-100m) using a spotting scope from a vehicle or tent. Mark-recapture analyses can be conducted using models within programs such as program MARK (White and Burnham 1999).

Summary of Conservation Action

While Burrowing Owls continue to undergo severe population decline throughout much of their range in North America, Wyoming constitutes a large part of the core range. And while population-trend data are not yet published for Wyoming, Burrowing Owls are still thought to be numerous and breeding successfully across much of the state. However, factors causing regional decline elsewhere are the same factors present in Wyoming. Pro-active management to maintain and enhance Burrowing Owl populations within the state are necessary to prevent local decline, and to prevent potential listing to Threatened or Endangered status. Below is a final summary of the primary conservation action-items necessary for maintenance of viable populations of Burrowing Owls in Wyoming:

- Conserve large, contiguous areas of short- and mixed-grass prairie and shrub-steppe.
- Conserve and enhance prairie dog populations throughout the state, and provide economic incentives to private landowners to make maintenance of prairie dog colonies profitable.
- Conduct standardized point-counts using call-broadcast along roadsides to determine distribution and estimate population trend.
- Increase public awareness about Burrowing Owl natural history, habitat, and conservation status. Increase cooperation with private landowners.
- Increase collaboration among state and federal wildlife and land management agencies to ensure effective management and mitigation strategies. Increase interstate and international collaboration to conserve Burrowing Owls throughout North America.

Tables and Figures

Table 1. Apparent nest success and productivity of a Burrowing Owl population in the Thunder Basin National Grasslands, WY 2001-2003 (Conway and Lantz *unpubl. data*).

	Nest Success[a]	Eggs/Nest				Young/Nest[b]				Fledge/Nest[c]			
	%	n	$\bar{x}$	SE	Range	n	$\bar{x}$	SE	Range	n	$\bar{x}$	SE	Range
2001[d]	71%	--	--	--	--	31	3.6	0.2	1 - 7	22	3.0	0.21	1 - 5
2002		12	5.2	0.30	4 - 7	51	3.9	0.21	0 - 7	41	2.8	0.27	0 - 7
2003	78%	22	6.9	0.41	3 – 9	66	3.95	0.27	0 - 8	60	3.0	0.28	0 – 7

[a] Apparent nest success: at least one juvenile successfully raised to ≥ 40days per nest (fledge age).
[b] Young ≥ 32days.
[c] Young ≥40days considered 'fledged'. Since this estimate, fledge age has changed to 44days (C. Conway, personal communication).
[d] Data limited due to lack of subterranean information (burrow videoscope used in 2002-2003).

Table 2. Official status of Wyoming populations of Burrowing Owls.

Common Name (Scientific Name)	Heritage Rank	Heritage State Rank Reasons	WY Cont. Rank	Wyoming Contribution Rank Reasons	Federal and State Status	County of Occurrence
Burrowing owl (Athene cunicularia [Speotyto cunicularia])	G4/S3	Moderate WY Range. High Biological Vulnerability. Moderate External Threats.	Low	Medium portion of its range in Wyoming, Wide continental distribution, and Uncertain security in Wyoming relative to other areas.	USFS R2 Sensitive, Wyoming BLM Sensitive, WYGF NSS4	all counties

HERITAGE RANKS: WYNDD uses a standardized ranking system developed by The Natural Heritage Network to assess the global and statewide conservation status of each plant and animal species, subspecies, and variety. Each taxon is ranked on a scale of 1-5, from highest conservation concern to lowest. Codes are as follows:
G - Global rank: rank refers to the rangewide status of a species.
S - State rank: rank refers to the status of the taxon (species or subspecies) in Wyoming. State ranks differ from state to state.
1 - Critically imperiled because of extreme rarity (often known from 5 or fewer extant occurrences or very few remaining individuals) or because some factor of a species' life history makes it vulnerable to extinction.
2 - Imperiled because of rarity (often known from 6-20 occurrences) or because of factors demonstrably making a species vulnerable to extinction.
3 - Rare or local throughout its range or found locally in a restricted range (usually known from 21-100 occurrences).
4 - Apparently secure, although the species may be quite rare in parts of its range, especially at the periphery.
5 - Demonstrably secure, although the species may be rare in parts of its range, especially at the periphery.

Table 3. 1992 wildlife agency survey results (adapted from James and Espie 1997). Agency personnel were asked to estimate population size, trend, limiting factors, and conservation status for Burrowing Owls within their jurisdiction.

Jurisdiction	Size[a]	Trend[b]	Factors[c]	Special Status
Alberta	Low 4	D/S	H, Ps	Yes
4	3	D	H, Ps, B	No
BC	1	D	H, Pr, B	Yes
California	4	D	H, Ps, Pr, Pe, B V	Yes
Colorado	4	D	H, Ps, B	No
Florida	4	S	H, Pr, V	Yes
Idaho	Low 4	S	H	Yes
Kansas	3	D	B	No
Manitoba	2	D	Ps, Pr, Pe, V	Yes
Minnesota	1	S	B, V	Yes
Montana	3	S	?	Yes
Nebraska	3	D	H, Ps	No
Nevada	4	D	H, B, Ps	No
New Mexico	4	S	H, Ps	No
North Dakota	3	S	H, B, Ps	No
Oklahoma	3	S	H, B	Yes
Oregon	Low 4	S	H, B	Yes
Saskatchewan	Low 4	D	H, Ps, F	Yes
South Dakota	3	S	H, B	Yes
Texas	Low 5	S	H, B	No
Utah	Low 4	D	H	Yes
Washington	3	D	H	Yes
Wyoming	Low 4	S	H	Yes

[a] 1 = 1-10 pairs, 2 = 10-100 pairs, 3 = 100-1000 pairs, 4 = 1000-10000 pairs, 5 = 10000-100000 pairs.
[b] D = decreasing, S = stable.
[c] H = habitat loss, B = burrow availability, Ps = pesticides, Pr = predators, Pe = persecution, V = vehicle collisions, F = food availability.

Table 4. Breeding Bird Survey results indicating population trends for Burrowing Owls for Wyoming, the surrounding region, and the United States (adapted from Sauer et al. 2002).

	1966-2001					1966-1979			1980-2001		
Area[a]	Trend[b]	P	n	95%	CI	Trend[b]	P	n	Trend[b]	P	n
Wyoming	-23.7	0.04	11	-42.3	-5.2	10.5	0.76	2	5.9	0.53	9
Wyoming Basin	-31.0	0.07	4	-53.6	-8.4	10.5	0.76	2	29.0	0.60	2
USFWS Region 6 Mountain-Prairie	-4.4	0.29	129	-12.6	3.7	-0.7	0.92	48	-0.2	0.95	103
United States	-1.5	0.57	291	-6.5	3.6	0.0	0.99	113	1.6	0.40	237
Survey-wide	-1.5	0.57	299	-6.5	3.6	0.2	0.96	117	1.5	0.41	241

[a] All areas were given data credibility ratings, indicated by a color that corresponded to a distribution map. All areas listed above were given a rating of (Y)=yellow: Data with a potential deficiency.
[b] Mean percent change per year.

Table 5. Results from standardized roadside surveys conducted within black-tailed prairie dog colonies in the Thunder Basin National Grasslands, WY, 2001-2003 (Conway and Lantz *unpubl. data*).

	Colonies Surveyed	Owls Detected	Occupancy Rate		Re-use Rate	
	#	#	Rate	%	Rate	%
2001	67	70	16 of 67	24%	--	--
2002	73	106	27 of 73	37%	9 of 16	57%
2003	73	139	29 of 73	40%	16 of 27	38%
All Years	--	315	--	--	6 of 16	38%

Figure 1. Burrowing Owl nesting in the Thunder Basin National Grasslands, northeastern Wyoming. Photograph by Masaki Watanabe, NHK, Japan Broadcasting Company, used with his permission.

Figure 2. Male and female Burrowing Owls, male on the left, female on the right. Lighter plumage on crown of male, distinct throat patch and brown barring on belly. Chocolate-brown coloration and white spotting of scapulars, white undertail coverts visible on female. Photograph by Masaki Watanabe, NHK, Japan Broadcasting Company, used with his permission.

Figure 4. Distribution of Burrowing Owls in North and Central America. Modified from NatureServe (B. Young, 2002) by B. Hamilton Smith, WYNDD.

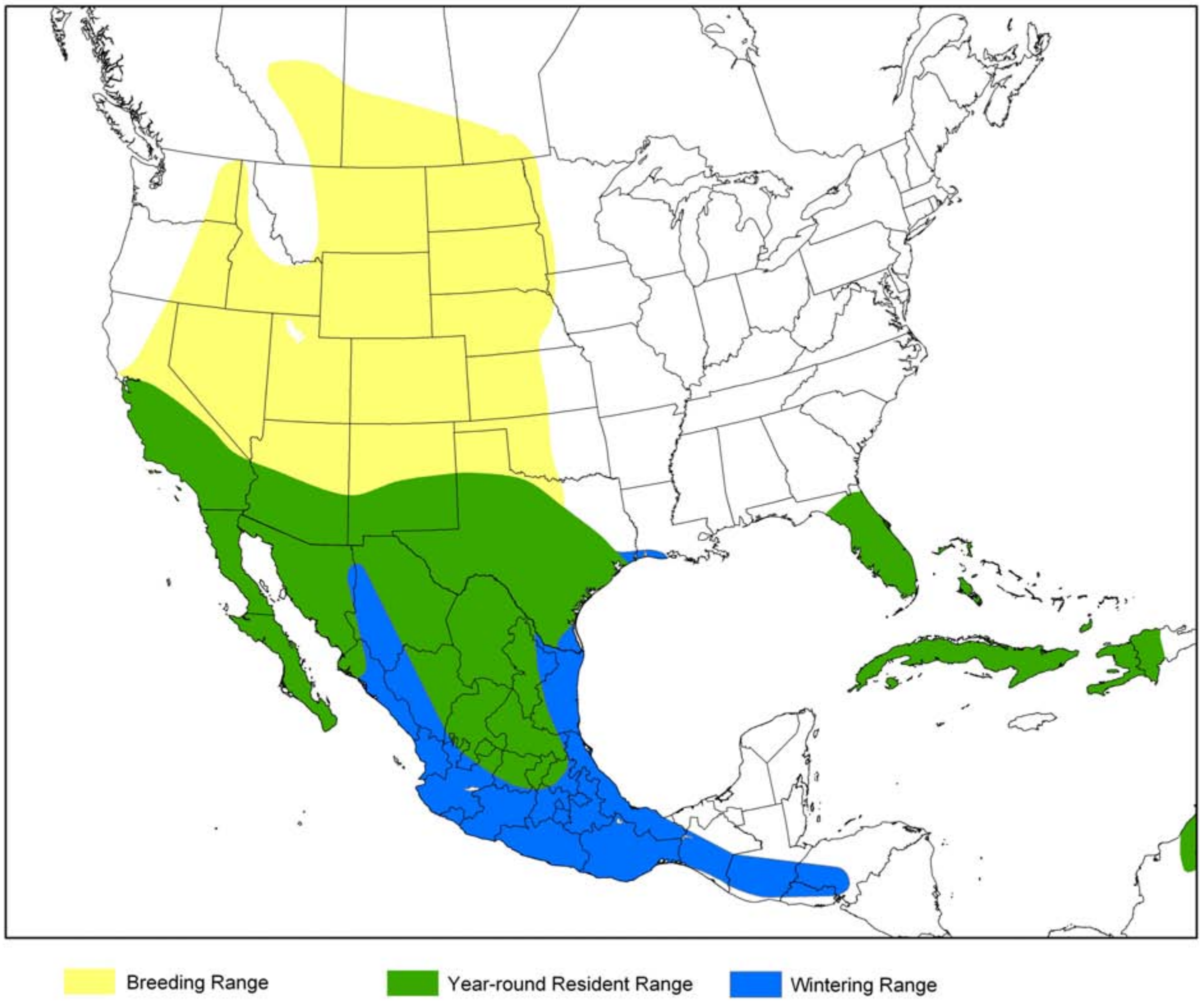


Figure 5. Distribution of Western Burrowing Owl (*A. c. hypugaea*) in the United States showing areas of range contraction (modified from Wellicome and Holroyd 2001).

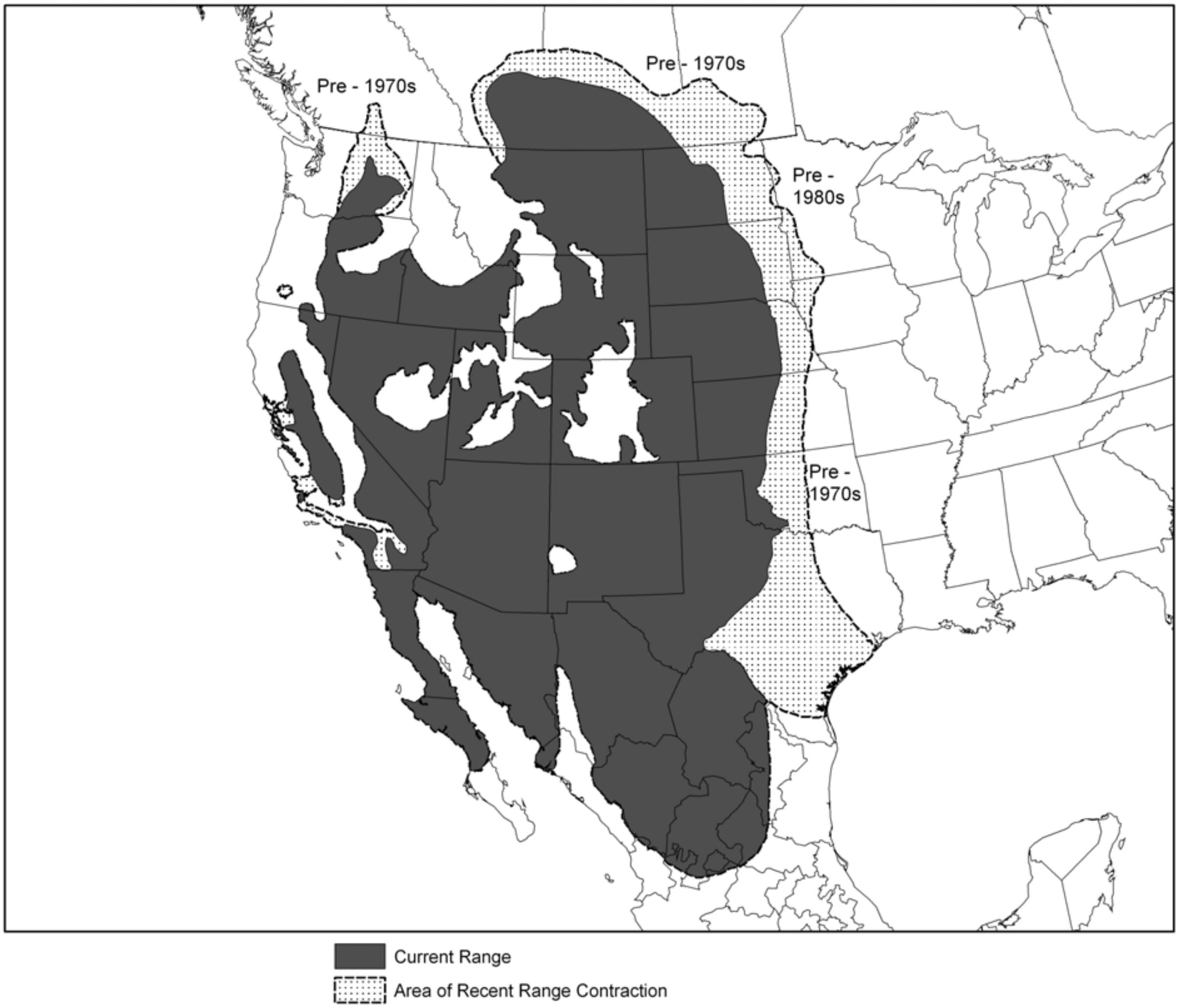


Figure 6. Comparison of projected and known distribution of Burrowing Owls in Wyoming. Green and yellow shaded areas represent projected distribution from GAP data (http://www.gap.uidaho.edu/Projects/States/, October 14, 2002). Green refers to the predicted presence of Burrowing Owls within the primary cover type, and yellow refers to the predicted presence of Burrowing Owls within the secondary cover type. Black squares represent reported sightings from the Wyoming Game and Fish Wildlife Observation database (WOS), and Gray squares represent confirmed Burrowing Owl locations (Korfanta et al. 2001, Conway and Lantz *unpubl. data*).

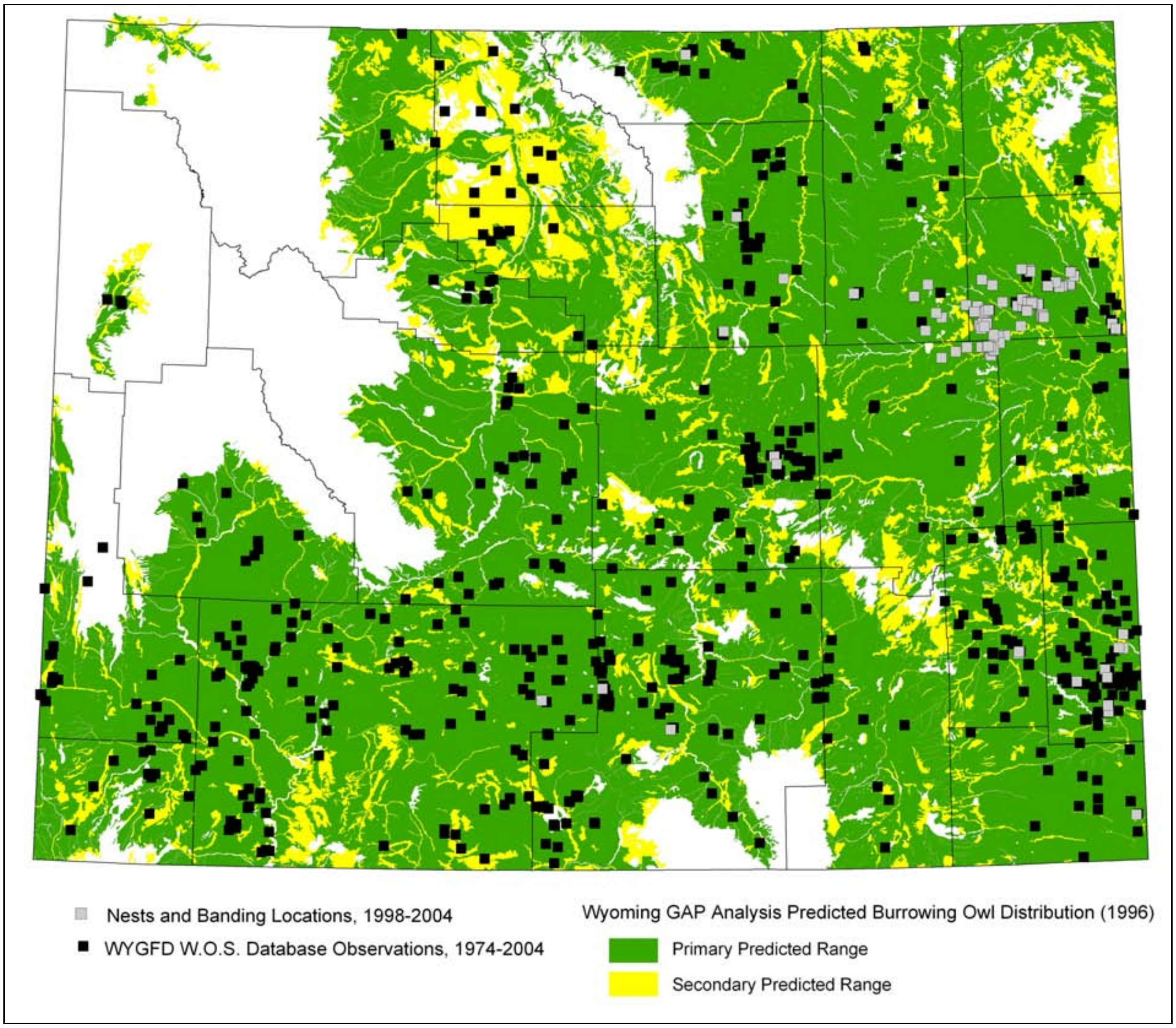


Figure 7. Burrowing Owl sightings within Wyoming, based on reports in the Wyoming Game and Fish Wildlife Observation (WOS) database as well as a 1999 survey effort within eastern Wyoming (Korfanta et al. 2001).

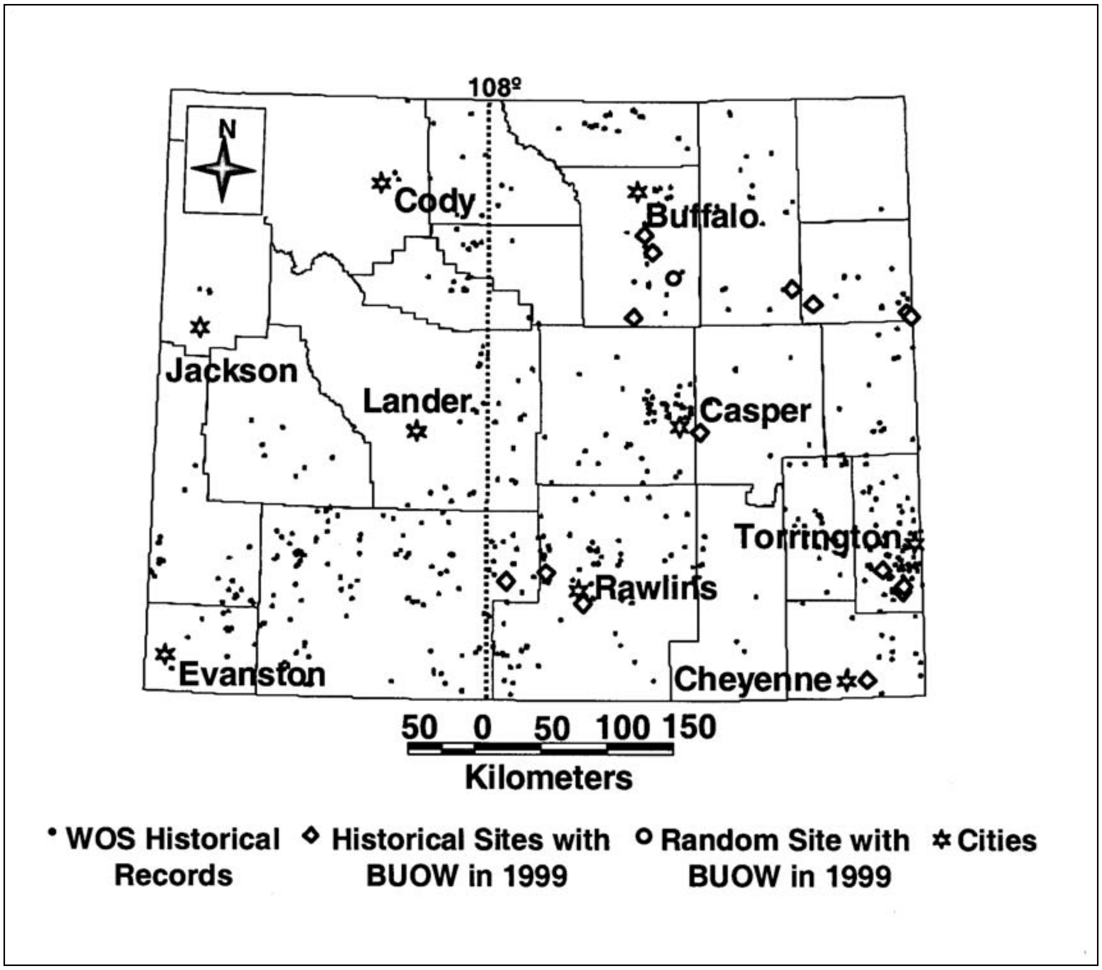


Figure 8. Burrowing Owl locations within Thunder Basin National Grasslands, Wyoming 2001-2004. Points represent nesting burrows occupied in at least one or more years, as well as individual sightings where nests were not determined (Conway and Lantz, *unpubl. data*).

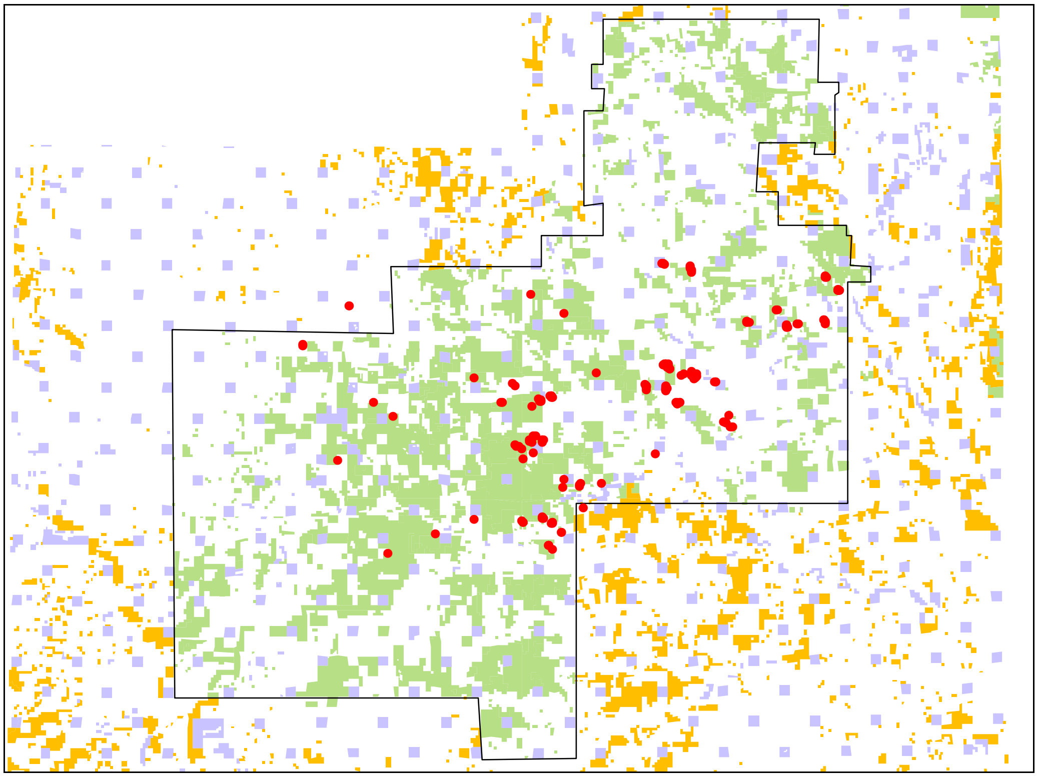


Figure 9. Example of Burrowing Owl habitat, taken in the Thunder Basin National Grasslands of northeastern Wyoming.

Figure 10. Number of Burrowing Owl records per year in the Wyoming Game and Fish Department's Wildlife Observation System (WOS). Significant decline in reported sightings began in 1986, the result of either declining Burrowing Owl abundance or decreasing interest in the WOS (Korfanta 2001).

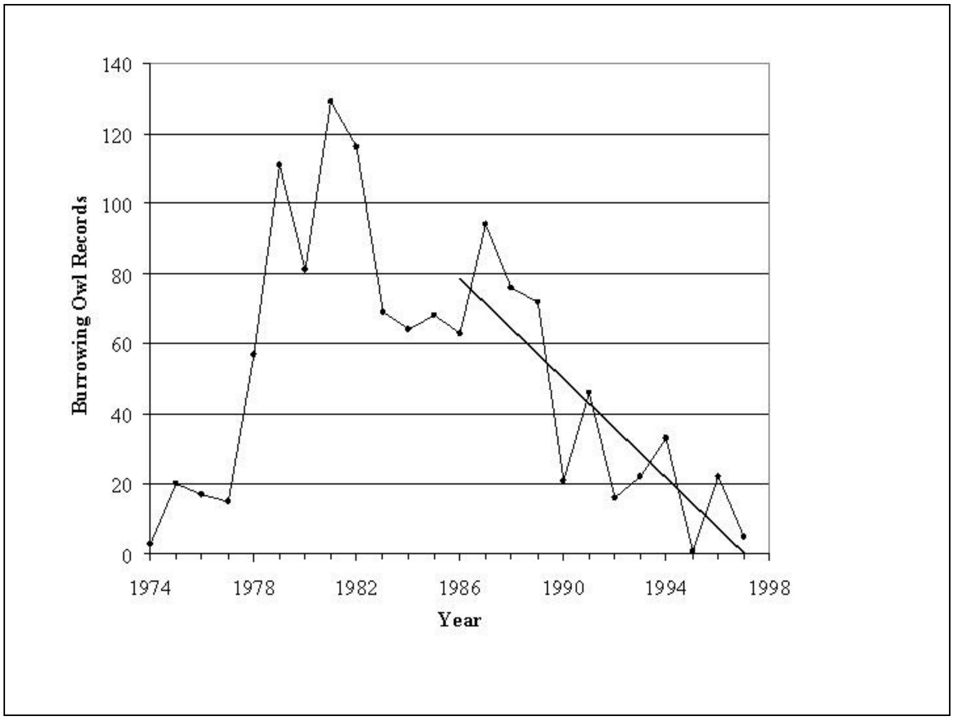
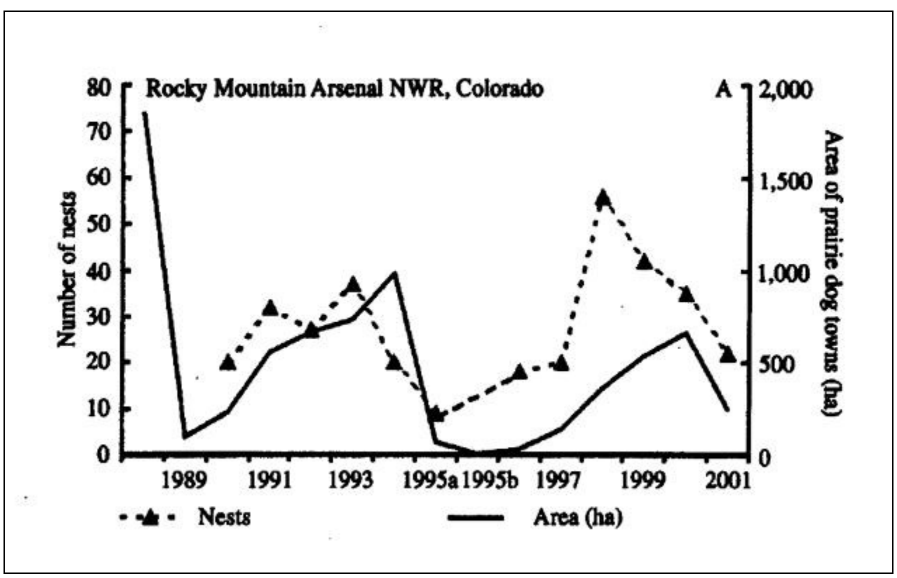


Figure 11. Fluctuations in area of prairie dog colonies, tracked by fluctuations in numbers of Burrowing Owl nests in the Rocky Mountain Arsenal National Wildlife Refuge, Colorado, from 1989-2001 (Lutz and Plumpton, as cited in Antolin et al. 2002).



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Appendix 1. Roadside survey protocol for Burrowing Owls

(see 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.)

Roadside point-count survey routes should be selected within some structured sampling frame to ensure that observers do not preferentially place survey routes in areas with high breeding densities. For example, we recommend establishing 1 point-count survey route within each township/range that falls within the known breeding range of burrowing owls in each state. Each survey route will follow a secondary road, beginning within the center 4 sections of each township/range (sections 15, 16, 21, and 22). Location of each route will be selected in advance of the survey based on perceived suitable habitat for burrowing owls. The location of these point-count survey routes should in no way be influenced by previous knowledge of burrowing owl observations, historic records, or known nest sites. If no suitable habitat is available within the center 4 sections, a route can be located in the surrounding 12 sections. We also recommend supplemental survey routes (in addition to the systematic survey routes outlined above) based on areas of known burrowing owl breeding locations. These routes should be treated separately from the systematic survey routes because they will be located in areas of known burrowing owl activity (current or historical).

We recommend that each survey route be ≥7.2 km (4.5 mi) in length and include 10 survey points separated by ≥0.8 km (0.5 mi). This interval will help ensure that observers do not re-count individual owls at adjacent points but still provide adequate detection probability. The exact location of each survey point should be chosen to provide an optimal viewing radius of the surrounding area. Adjacent survey points may be located >0.8 km (0.5 mi) apart if no suitable habitat is available or visibility of surrounding habitat is not optimal at the 0.8 km interval. The permanent location of each survey point should be marked or recorded using a GPS receiver so that the exact survey location can be re-surveyed in future years.

Because detection probability associated with a single point-count survey is only 64%, we recommend 3 replicate surveys of each route so that overall detection probability will be 95%. Surveys should be conducted after birds have returned from migration but prior to the date when young disperse (e.g., 15 Apr–7 Aug in Wyoming; 1 Apr–21 Jul in Washington). One replicate survey should be conducted during each of 3 30-day survey windows with each survey window separated by 10 days (e.g., 20 Apr–19 May; 30 May–28 Jun; 9 Jul–7 Aug in Wyoming). This approach will ensure survey effort during each of 3 nesting stages (pre-incubation, incubation/hatching, and nestling) that differ in vocal and visual detection probability. Standardized burrowing owl surveys should include an initial 3-min passive segment followed by a 3-min call-broadcast segment. For the 3-min call-broadcast segment, we recommend a series of 30 sec call-broadcasts (*coo-coo* call and alarm call-broadcast at 90 dB measured 1 m in front of the speaker) interspersed with 30 sec of silence.

Surveys should be restricted to the early morning (e.g., 0.5 hr before sunrise until 0900 hr) and evening hours (e.g., 1700 hr until 0.5 hr after sunset) because vocalization probability and above-ground activity is often higher during these times compared to mid-day (Grant 1965, Climpson 1977, Johnsgard 1988). However, more studies are needed to evaluate daily variation in detection probability during all stages of the nesting cycle. Surveys should not be conducted during rain or when wind speed is >20 km/hr. At each point, observers should record (1) the number of adult owls, (2) the number of juvenile owls, and (3) the number of presumed nest sites. Implementing this survey protocol over a large geographic area is feasible. For example, we estimate approximately 5 seasonal surveyors could conduct all of the surveys needed for the state of Washington (approx. 450 routes) following this recommended survey protocol.