Population Dynamics and Conservation of the Western Burrowing Owl (*Athene cunicularia hypugaea*) in the United States and Canada: a 20-year update

Dinâmica populacional e conservação da coruja-buraqueira-ocidental (*Athene cunicularia hypugaea*) nos Estados Unidos e no Canadá: atualização após 20 anos

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ABSTRACT

The Western Burrowing Owl (*Athene cunicularia hypugaea*) has been the focus of much research, monitoring, and conservation efforts since the first indications of population declines in the 1960s. Despite this focus and continuing declines, burrowing owls remain endangered in Canada, threatened in Mexico, and while not yet listed at the federal level in the United States of America (US), they are listed as endangered, threatened, or a species of concern in most western states. I examined the population dynamics of Western Burrowing Owls using two major long-term, standardized avian counts, the Breeding Bird Survey (BBS) and Christmas Bird Count (CBC), and reviewed their conservation status as I did 20 years ago to assess changes occurring over this time. BBS data for the US and Canada reveal that the 1966-2017 trend is slightly more than a 1% loss per year. Almost all western US states continue to show declining numbers (0.2-4.9%). CBC data for the US indicate that relatively few owls are seen on CBCs (0.03-0.05 owls/party hour), limiting its use. In addition to BBS and CBC data, a review of the peer-reviewed literature from 1997-2017 reveals that slight to steep population declines have been reported in the US and Canada, and that in many locations where Western Burrowing Owls formerly were common, they have disappeared at an alarming rate. Surveys conducted at historical nesting sites

have found that only a small percentage of the sites are still occupied. Elimination of fossorial mammals through control programs, habitat loss, and disease appears to be a primary factor responsible for owl declines. I suggest that the most effective way to conserve this owl is to protect fossorial mammals and their habitats, which should include eliminating control programs and placing real limits on changing land-use for agricultural and other development. Further, the conservation status of this owl at the federal and state levels in the US should be revisited and adjusted to more accurately reflect its continuing decline.

Keywords: *Athene cunicularia hypugaea*, survey techniques, conservation, population dynamics, Western Burrowing Owl

RESUMO

A coruja-buraqueira-ocidental (*Athene cunicularia hypugaea*) tem sido o foco de vários esforços de investigação, monitorização e conservação desde os primeiros indícios de declínio da população na década de 1960. Apesar desse esforço, o declínio tem sido contínuo e a coruja-buraqueira continua classificada como "em perigo" no Canadá, "ameaçada" no México e, embora ainda não esteja listada ao nível federal nos Estados Unidos da América (EUA), está classificada como "em perigo", "ameaçada" ou "preocupante" na maioria dos estados ocidentais. Examinei a dinâmica populacional de corujas-buraqueiras-ocidentais usando duas contagens de aves padronizadas de longo prazo, o *Breeding Bird Survey* (BBS) e o *Christmas Bird Count* (CBC), e revi seu estatuto de conservação, como fiz há 20 anos, para avaliar as alterações ocorridas durante esse período de tempo. Os dados do BBS para os EUA e o Canadá revelam que a tendência de 1966-2017 é ligeiramente superior a um declínio de 1% por ano. Quase todos os estados do oeste dos EUA continuam a apresentar um declínio (0,2-4,9%). Os dados do CBC para os EUA indicam que são observadas relativamente poucas corujas (0,03-0,05 corujas/hora), o que limita a sua utilização. Além dos dados das contagens BBS e CBC, a revisão da literatura de 1997-2017 revela que foram relatados declínios populacionais ligeiros a acentuados nos EUA e no Canadá, e que a espécie desapareceu a um ritmo alarmante em muitos locais onde anteriormente era comum. Pesquisas realizadas em locais históricos de nidificação revelaram que apenas uma pequena percentagem dos locais ainda continua ocupada. A eliminação de mamíferos fossoriais através de programas de controlo, perda de habitat e doenças parece ser o principal fator de declínio da coruja-buraqueira. A medida mais eficaz de conservação desta espécie deverá ser a proteção dos mamíferos fossoriais e dos seus habitats, o que deve incluir a eliminação dos programas de controlo e a imposição de limites reais às alterações do uso do solo relacionadas com o desenvolvimento agrícola e outros. Adicionalmente, o estatuto de conservação da coruja-buraqueira aos níveis federal e estatal nos EUA deve ser revisto e ajustado para refletir com mais precisão o seu contínuo declínio.

Palavras-chave: *Athene cunicularia hypugaea*, conservação, coruja-buraqueira-ocidental, dinâmica populacional, técnicas de monitorização

Introduction

The Western Burrowing Owl (*Athene cunicularia hypugaea*; hereafter BUOW) is an obligate species of prairie grassland ecosystems of the mid-western and western United States, Canada, and Mexico (Klute et al. 2003; Poulin et al. 2011) (Fig. 1.). They are found primarily in open areas with short vegetation and bare ground in grassland, desert, and shrub-steppe habitats. The vast majority of BUOWs are dependent upon the presence of fossorial mammals whose burrows are used for nesting and roosting (Klute et al. 2003; Johnsgard 2002; Poulin et al. 2011).

Populations of BUOWs have declined both locally and regionally over their range in North America (Sheffield 1997*a*; Holroyd et al. 2001; Klute et al. 2003; Poulin et al. 2011). Some population declines have been very serious (e.g., > 10% annually; Klute et al. 2003; Poulin et al. 2011). The primary threat across their range is habitat loss due to changes in land-use, conversions for agriculture and urban development, and habitat degradation and loss due to major reductions of fossorial mammal populations (Davidson et al. 2012).

The close ecological association between BUOWs and prairie dogs, mainly black-tailed prairie dogs, is well-established and unequivocal (Butts and Lewis 1982; Desmond et al. 2000; Sidle et al. 2001; Winter and Cully 2007; Poulin et al. 2011). Widespread conversion of grassland to agriculture, extensive overgrazing, and desertification have resulted in 20-80% declines in grassland area across all continents (White et al. 2000). This has resulted in substantial reductions in the amount of preferred habitat for fossorial mammals, and subsequent population declines in fossorial mammals and the large number of species which rely on them (Ceballos et al. 2010). In addition, intensive control programs (poisoning, shooting) and sylvatic plague epizootics have seriously reduced prairie dog populations by an estimated 98% since 1900 (Hoogland 2006).

Burrowing Owls generally are found at low densities with relatively large distances between individual or loose clusters of pairs. Estimating the population size of BUOWs over large areas is difficult; this is a species which requires concerted effort in which to survey due to their distribution and particular life history traits. One way in which to attempt to assess burrowing owl population sizes and trends is the use of two long-term avian surveys, the Breeding Bird Survey (BBS) and the Audubon Christmas Bird Counts (CBC). The BBS is a standardized, early summer survey of breeding birds administered by the US Geological Survey (USGS), and has been conducted every year since 1966. The Audubon CBC is a standardized, early winter survey of birds administered by the National Audubon Society (NAS), and has been conducted every year since 1900. Together, the BBS and CBC can provide an estimate of avian population sizes and trends throughout the year (Kirk and Hyslop 1998; Butcher and Niven 2007; Langham et al. 2015). The strengths of these databases are that they are long-term, are standardized, include measures of effort recorded for each count, and are peer-reviewed (Sauer et al. 2004; Soykan et al. 2016; Rosenberg et al. 2017).

The objectives of this study were to (1) utilize long-term avian databases (e.g., BBS, CBC) to assess population status and trends of BUOWs; (2) follow up on similar analysis conducted by Sheffield (1997) and Klute et al. (2003) to assess estimated population changes over time; (3) compare the conservation statuses of BUOWs from 1997-2017; and (4) examine the scientific literature from 1997-2017 for papers dealing with BUOW population status and trends.

Figure 1 - North American distribution (from Klute et al. 2003) of the Western Burrowing Owl.

Figura 1 - Distribuição da coruja-buraqueira-ocidental na América do Norte (adaptado de Klute et al. 2003).

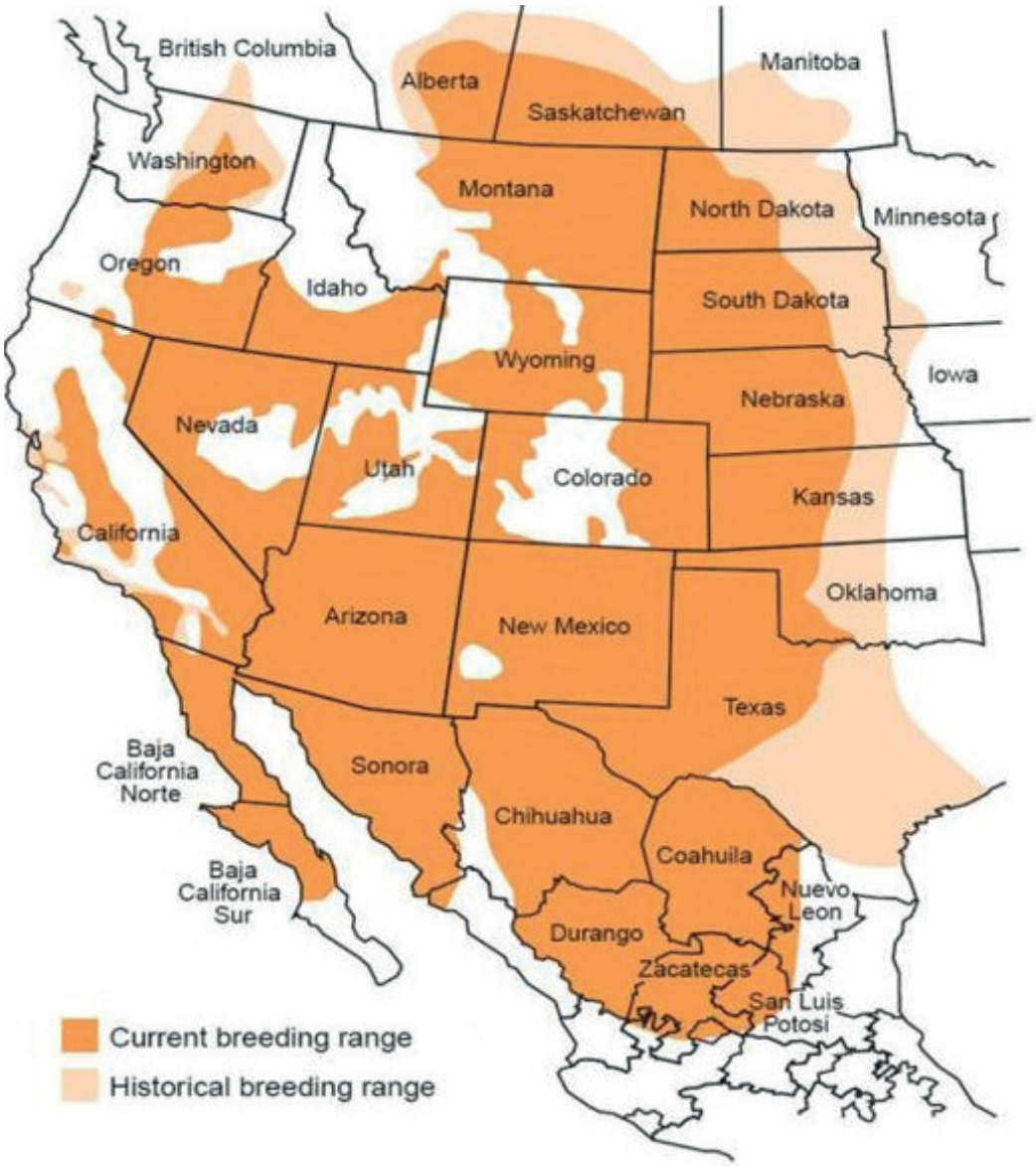


Figure 2 - Western Burrowing Owl Breeding Bird Survey relative abundance data (2011 versus 2017).

Figura 2 - Abundância relativa da coruja-buraqueira-ocidental no Breeding Bird Survey (2011 versus 2017).

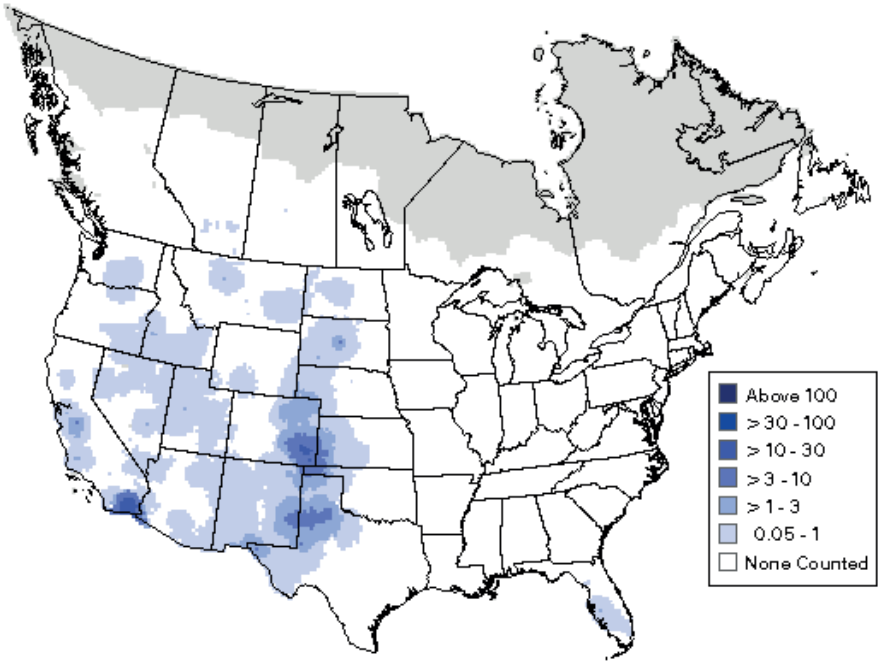


Figure 3 - Western Burrowing Owl Breeding Bird Survey trend data (2011 versus 2017).

Figura 3 - Tendência da coruja-buraqueira-ocidental no *Breeding Bird Survey* (2011 *versus* 2017).

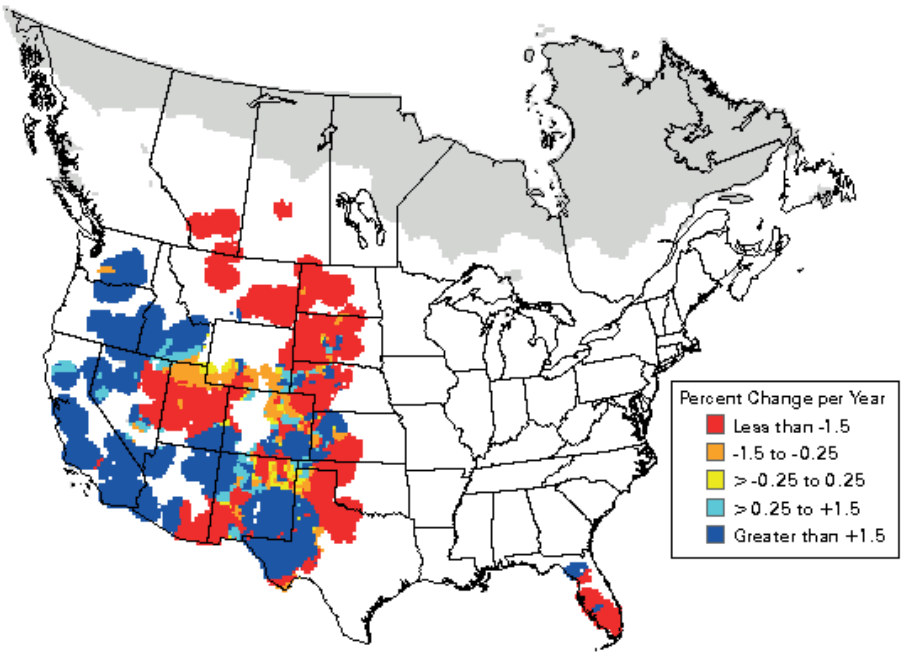


Table 1 - Western Burrowing Owl population monitoring - Breeding Bird Survey (% change/year) per country.
* = p<0.05

Tabela 1 - Monitorização da população da coruja-buraqueira-ocidental – *Breeding Bird Survey* (% alteração/ano) por país.

AREA	1966-1994	1966-2006	1966-2011	1966-2015
United States	- 0.5 (n=238)	- 1.5 (n=334)	- 1.0 (n=553)*	- 0.91 (n=555)*
Canada	n/a (n=7)	- 13.5 (n=7)	- 7.8 (n=25	- 6.42 (n=28)
North America	- 0.6 (n=245)	- 1.6 (n=341)	- 1.1 (n=578)*	- 1.1 (n=578)*

Table 2 - Western Burrowing Owl population monitoring - Breeding Bird Survey (% change/year) per state (US).
* P<0.05

Tabela 2 - Monitorização da população da coruja-buraqueira-ocidental - *Breeding Bird Survey* (% alteração/ano) por estado (EUA).

STATE	Sheffield (1997)	Sauer et al. (2007)	Sauer et al. (2011)	Sauer et al. (2017)
California	5.3 (32)*	4.2 (33)*	-1.8 (60)	-1.79 (61)
Colorado	-3.8 (25)	-5.8 (44)	-1.0 (55)	-0.43 (55)
Nebraska	6.0 (15)	32.8 (16)	3.2 (29)	0.85 (26)
New Mexico	-0.6 (22)	3.4 (39)	1.0 (56)	1.08 (54)
North Dakota	4.2 (16)	-3.8 (13)	-4.9 (28)*	-6.08 (28)*
South Dakota	-5.8 (19)	-4.8 (11)	-2.2 (32)	-2.92 (32)*
Texas	-1.4 (22)	0.2 (36)	-1.5 (54)	-1.22 (51)

Methods

Population numbers and trends presented here are derived from 50 years (1966-2016) of North American Breeding Bird Survey (BBS) data (Sauer et al. 2017) and 116 years (1900-2016) of Christmas Bird Count (CBC) data (National Audubon Society 2017). Long-term avian population databases such as the BBS and CBC are acknowledged to be potentially valuable indicators of patterns of avian biogeography and population trends (Sauer et al. 2004; Sauer et al. 2013). The BBS and CBC data allow analysis of abundance and distribution of avian species during the breeding season (late spring/early summer) and during early winter, respectively. Importantly, studies which have analyzed both CBC and BBS data together have found CBC trend estimates to be broadly congruent with estimates based on the BBS (Link and Sauer 2007; Soykan et al. 2016). Further, I compared state, provincial, and national conservation statuses of BUOWs to look for changes over this 20-year period. Finally, I examined the burrowing owl scientific literature over this 20-year period for papers dealing with BUOW trends, distribution, or conservation status in order to provide additional insight into local and/or regional population dynamics.

Results

Breeding Bird Survey

In the United States, the national BBS data show over a 50-year period a fairly consistent and statistically significant decline of 0.91%/yr, including a 0.41%/yr decline over the past 20 years, in the overall BUOW population (Table 1, Fig. 2 and 3). For North America overall, the BBS data show over a 50-year period a decline of 1.1%/yr, including a 0.38%/yr decline over the past 20 years, in the overall BUOW population (Table 1). In Canada, the BBS data show over a 50-yr period a precipitous decline of 6.42%/yr. In the United States, the BBS data by state indicate that, of the seven states (California, Colorado, Nebraska, New Mexico, North Dakota, South Dakota, Texas) analyzed by Sheffield (1997*a*), five states (California, Colorado, North Dakota, South Dakota, Texas) have demonstrated 20-year (long-term) declining population trends (Table 2). Population declines in both North Dakota (6.08%/yr) and South Dakota (2.92%/year) were statistically significant. Overall, the states of California and North Dakota have shown the sharpest declines in numbers in the past 20 years; California went from an increase of 5.3%/year in 1997 to a decline of 1.79%/yr in 2017, and North Dakota went from an increase of 4.2%/yr in 1997 to a decline of 6.08%/yr in 2017 (Table 2).

There are BBS data for 10 additional states (Arizona, Idaho, Kansas, Montana, Nevada, Oklahoma, Oregon, Utah, Washington, Wyoming), and of these states, seven of them show population declines ranging from 0.17%/yr in Oklahoma to 4.70%/yr decline in Washington; the decline of 4.04%/yr in Kansas was the only one which was statistically significant (Table 3).

In Canada, BUOW declines were 6.90%/yr in Alberta and 6.17%/yr in Saskatchewan (Table 3).

Christmas Bird Count

The CBC data indicate that BUOWs are exceedingly rare winter inhabitants of Canada (only three records in the past 20 yrs), and uncommon inhabitants of the United States (the majority of BUOWs winter in Mexico), with a mean of only 454.2 owls found in the United States each year over the past 20 years (Table 4). Over this time, annual numbers ranged from 291-600 owls, with the number of BUOWs/party hours (a measure of effort) being low (0.0039) across the United States, ranging from 0.0028-0.0049. This low average number of BUOWs/party hour means that CBC participants would need to search 256.4 hrs to find one BUOW. As far as BUOWs at the state level, California has the most early winter burrowing owls by far (=168.4), followed by Texas (=33.5), Arizona (=23.0), and New Mexico (=14.6). At the state level, the number of BUOWs/party hours ranges from 0.0047-0.0127. BUOWs in southern portions of California and Arizona are year-round residents, and this may complicate CBC trend data.

Conservation Status

On the international level, Burrowing Owls have a Global Heritage Rank of G4 (Table 5), which means that they are apparently secure globally though the species may be quite rare in parts of its range. The IUCN lists Burrowing Owls as Least Concern ranking on the IUCN Red List, largely because of their large distribution throughout the Western Hemisphere (IUCN 2017). Further, Burrowing Owls are a CITES Appendix II species, which means that, although they are not necessarily threatened with extinction, they may become so unless trade is closely controlled (CITES 2017). The legal trade in wild BUOWs from North America was an exceedingly rare activity between 1975-2015 (Panter et al. 2019), and there are no strong

Table 3 - Western Burrowing Owl population monitoring - Breeding Bird Survey (% change/year) per state (US) and province (Canada).

Tabela 3 - Monitorização da população da coruja-buraqueira-ocidental - *Breeding Bird Survey* (% alteração/ano) por estado (EUA) e província (Canadá).

OTHER STATES	Sauer et al. (2007)	Sauer et al. (2011)	Sauer et al. (2017)
Arizona	18.7 (11)	1.2 (21)	1.66 (23)
Idaho	10.2 (9)*	-0.1 (16)	-0.72 (14)
Kansas	2.6 (17)	-3.2 (24)	-4.04 (24)*
Montana	-15.2 (11)	-2.1 (25)	-2.08 (24)
Nevada	8.0 (11)	-0.2 (19)	1.96 (19)
Oklahoma	-4.8 (11)	-0.2 (13)	-0.17 (13)
Oregon	1.1 (11)	-1.0 (18)	-0.94 (21)
Utah	7.9 (21)	-1.5 (42)	0.01 (46)
Washington	-4.0 (8)	-2.3 (17)	-4.70 (17
Wyoming	-20.1 (12)	0.7 (28)	-0.19 (31)
PROVINCES			
Alberta	-11.9 (5)	-6.2 (12)	-6.90 (15)
Saskatchewan	-26.0 (2)	-8.5 (12)	-6.17 (13)

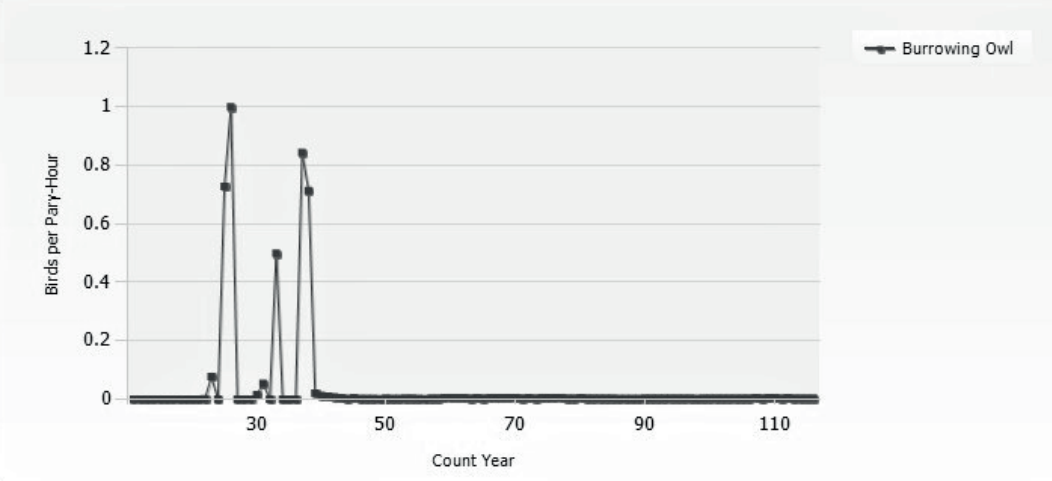
Table 4 - Western Burrowing Owl population monitoring in 1900-2016, from Christmas Bird Count data (National Audubon Society 2017).

Tabela 4 - Monitorização da coruja-buraqueira-ocidental no *Christmas Bird Count* entre 1900 e 2016 (National Audubon Society 2017).

STATE	# (1997-2016)	mean # / yr	# / party hrs (effort)
United States	9,084	454.2	0.0039
California	3,368	168.4	0.0127
Texas	670	33.5	0.0047
Arizona	459	23.0	0.0074
New Mexico	292	14.6	0.0108

Figure 4 - Western Burrowing Owl population monitoring in 1900-2016, from Christmas Bird Count data (National Audubon Society 2017).

Figura 4 - Monitorização da coruja-buraqueira-ocidental no *Christmas Bird Count* entre 1900 e 2016 (National Audubon Society 2017).



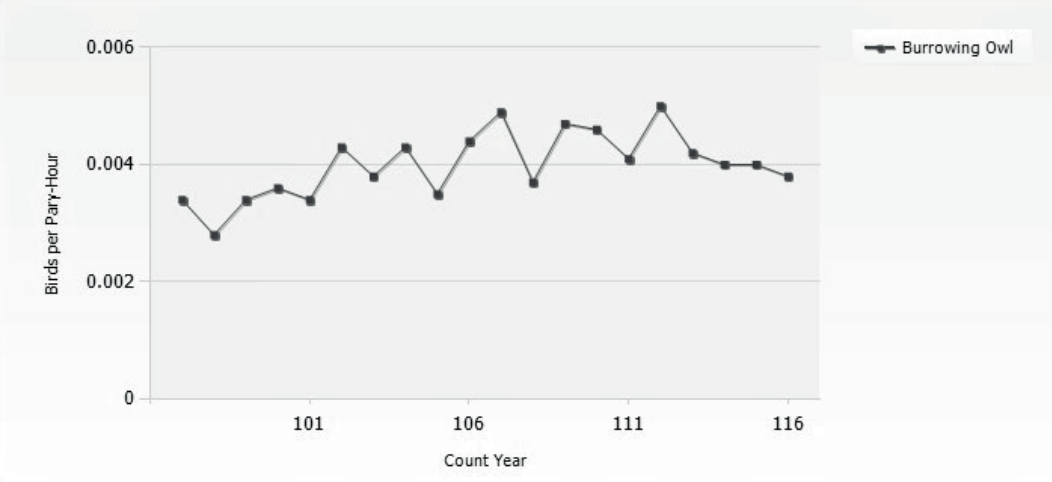
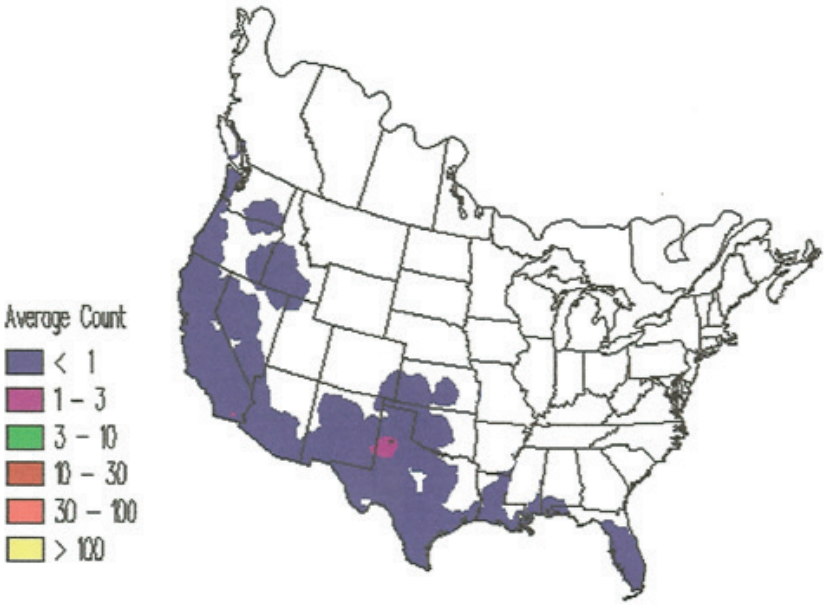


Figure 5 - Western Burrowing Owl population monitoring in 1959-1988, from Christmas Bird Count data (Sauer et al. 1996).

Figura 5 - Monitorização da coruja-buraqueira-ocidental no *Christmas Bird Count* entre 1959 e 1988 (Sauer et al. 1996).



cultural beliefs that suggest legal or illegal trade of this species in North America (D.H. Johnson, pers comm). At the federal level, BUOWs are listed as endangered in Canada, threatened in Mexico, and not listed in the United States. Burrowing Owls are federally protected in the United States, Canada, and Mexico by the Migratory Bird Treaty Act. In the United States, BUOWs were included as a Category 2 Candidate Species from 1994-1996. The US Fish and Wildlife Service's Birds of Conservation Concern reports (USFWS 2003, 2009) include the BUOW as a Bird of Conservation Concern at the national level, in 3 USFWS Regions, and in 9 Bird Conservation Regions.

At the provincial level in Canada, BUOWs are listed as endangered in Alberta, British Columbia, Manitoba and Saskatchewan. In the United States, BUOWs are listed as endangered in Iowa and Minnesota, threatened in Colorado, and of special concern in Arizona, California, Montana, Oklahoma, Oregon, Utah, Washington, and Wyoming. In Idaho, the BUOW is listed as a species of greatest conservation needs in the state wildlife action plan, and in North Dakota, the BUOW is listed as a level II species of conservation priority. The BUOW is not listed in Kansas, Nebraska, Nevada, New Mexico, South Dakota or Texas. Over the past 20 years, the Canadian provincial designations have not changed, and the United States state designations have changed slightly in favor of more protection for the BUOW. Notable upgrades in status have come in Arizona (from no listing to Special Concern) and Colorado (from undetermined to Threatened).

Western Burrowing Owl Scientific Literature (1997-2017)

Overall, the literature regarding population status/trends for BUOW indicates that slight to steep declines over decades have occurred across its range in the United States and Canada (Table 6). These declines are particularly steep in Canada. In locations where

Table 5 - Conservation Status for the Western Burrowing Owl – International, National, and State/Provincial levels.

Tabela 5 - Estatuto de conservação da coruja-buraqueira-ocidental – níveis Internacional, Nacional e de Estado/Província.

INTERNATIONAL LEVEL	Global Heritage Rank – G4 (apparently secure globally though it may be quite rare in parts of its range). CITES Appendix II IUCN Least Concern	
	COUNTRY	**STATUS**
FEDERAL LEVEL	Canada United States Mexico	Endangered None*1 Threatened
	COUNTRY	**STATUS**
STATE/PROVINCIAL LEVEL	Canada	Endangered – Alberta, British Columbia, Manitoba, Saskatchewan
	United States	Endangered – Iowa, Minnesota

BUOWs were formerly common (e.g., California, North Dakota, Texas), they are disappearing at an alarming rate. Major threats are habitat fragmentation/loss, human disturbance, vehicle collisions, continued pesticide use (especially rodenticides), prairie dog control, and prairie dog mass mortality due to sylvatic plague, and climate change, including accelerated extreme climatic events (e.g., extreme rainfall, drought, etc.). Returning to conduct surveys at historical nesting sites is very important; such efforts have generally found that only a small percentage of these sites are still occupied.

Discussion

Over the past 20 years, based on BBS and CBC data, BUOW populations have continued to decline in most locations in the United States and Canada. BBS data show that the rate of annual decline for the United States and Canada combined over 50 years was 1.1%/yr, and over 20 years was 0.38%/yr. The rate of annual decline in Canada over 50-years was 6.42%/yr - an incredibly sharp decline.

In the United States, six of the seven states examined by Sheffield (1997*a*) have demonstrated 20-year substantially declining population trends, and the other state (New Mexico), which showed a slightly positive population trend, has other (non-BBS) evidence of substantial population declines (Arrowood et al. 2001; Cruz-McDonnell and Wolf 2016; Grimason 2016). Three United States states which serve as good case studies for serious declines of BUOWs are Oklahoma, North Dakota, and California. These states have shown the sharpest declines in the numbers of owls over the past 20 years. Sheffield and Howery (2001) found that BUOWs in Oklahoma had declined 4-7% over the past 10 yrs (1990-2000). They estimated 800-1000 BUOWs breeding in the state, most occurring in the three panhandle counties. BBS data show that BUOW populations have significantly decreased (12.3% annually) in the state. BUOW populations in

North Dakota have declined >11.0% over 20 years, and loss of habitat due to greatly accelerating rates of industrial (oil/gas) development has been a major driver of these declines. In California, BUOWs have gone from an increase of 5.3%/yr to a decline of 1.79%/yr over this 20-year period, a decrease of >7.0%. BUOWs in the state were found to be disappearing from many historic locations, especially in rapidly urbanizing areas, and a few disjunct populations were found in areas where they were not known to occur, such as adjacent to water conveyance structures in the Sonoran Desert (Wilkerson and Siegel 2011). In southern California, BUOWs were found to have experienced a 27% drop in the numbers of breeding individuals in the Imperial Valley (Manning 2009). This decline is of considerable concern because >80% of California's BUOWs are found in the Imperial Valley (Manning 2009). Further, BUOWs in San Diego County declined from 250-300 pairs in the late 1970s-early 1980s to only 46 pairs in 2007 (Lincer and Bloom 2007). In northern California, long-term censusing of BUOWs revealed declining populations in many cases, especially in urban areas such as the San Francisco Bay and Bakersfield areas (Barclay et al. 2010; Townsend and Lenihan 2007; Wilkerson and Siegel 2010). In the case of California, greatly accelerating rates of habitat loss through urbanization and agricultural expansion across much of the state is a major driver of these declines.

The CBC data show that an average of 454.2 owls along with relatively low number of owls/party hours counted each year over the past 20 years, meaning that BUOWs are not common winter residents in the United States or Canada, and thus the usefulness of CBC data for BUOWs is limited.

These findings are consistent with the overall BBS and CBC data for BUOWs, which have shown a decline in numbers since at least the mid-1970s (James and Ethier 1989; Sheffield 1997*a*). In the United States, BBS data has been used to document changes in distributional limits of the BUOW from 1967-2008 (Macias-Duarte & Conway 2015). They found that its breeding range has been receding near its northern, western, and eastern edges. Their statistical model also detected population declines in California and eastern Washington, locations where maps based on BBS route-specific estimating equations predicted significant population increases. While there are few BBS routes in Mexico, limited observations in northwestern Mexico indicate that BUOW distribution may be changing as they seemingly are attracted to the expansion of irrigated agriculture, constructed waterways, and suburban areas in arid deserts. Another study which used BBS data examined geographic patterns in population trends of BUOWs throughout their breeding range in the United States in relation to presence of burrowing mammals (Conway 2018). Findings include that population declines were most precipitous on the northern and southern edges of their breeding range, and that population declines were most apparent in portions of their range where they rely primarily on Richardson's ground squirrels (*Urocitellus richardsonii*), California ground squirrels (*Otospermophilus beecheyi*), black-tailed prairie dogs (*Cynomys ludovicianus*), and badgers (*Taxidea taxus*; Conway 2018). In Canada, Kirk and Hyslop (1998) used a combination of BBS data (1966-1994 and 1985-1994) nationally and for seven separate ecozones, CBC data (1959-1988), migratory counts from hawk watches, and specific research projects to examine population trends and status of 37 taxa of Canadian raptors, including BUOWs. BBS data showed significant declines for BUOWs in Canada.

A large and very important unknown with BUOWs is their status in Mexico (Klute et al. 2003; Poulin et al. 2011). There are a very limited number of BBS routes and CBC count circles in Mexico, so regional or national population estimates and trends are not available. As far as strengths and weaknesses of BBSs and CBCs related to BUOWs, the strengths are that BUOWs are crepuscular, territorial, and the openness of the land-

scapes they occupy is advantageous for visual detection. The major weakness of BBSs is that many BUOW populations do not occur near roads, so they would not be detected by the road-based BBS efforts. Uneven topography, even slight hills, significantly reduces BUOWs detection rates as owls within 400 m of survey points are blocked from view (D.H. Johnson, pers comm.). This results in substantially reduced detection rates of owls. The major weaknesses of CBCs are that most BUOWs do not winter in Canada or the United States, and owls detected within CBC areas are likely year-round residents, so numbers are both very low and detecting trends in migratory owls are unreliable at best.

Threats

BUOWs face a number of threats to their populations, including habitat degradation/loss, which is highlighted by land conversion for agriculture and urban development, burrowing mammal population reduction, contaminants, climate change, vehicle collisions, disturbance, energy production, and cumulative effects.

Habitat degradation/loss through land conversion for agricultural expansion also includes related actions such as mowing, burning, and grazing. Between 2008 and 2016, >80% of new cropland in the United States came from grassland ecosystems and, of those converted grasslands, about 880,000 ha were intact grasslands (Lark et al. 2018). However, despite a slowdown in cropland expansion during the most recent years, widespread conversion of habitat to crop production has continued at a rate of nearly 400,000 ha/yr (Lark et al. 2018). This represents a clear and continuing threat to natural ecosystems and the wildlife populations who occupy them. Habitat degradation/loss through land conversion for urban development, including residential and commercial development, has been continual and ever-expanding for many decades (Alig et al. 2004; d'Amour et al. 2017). In the United States, there was a 34% increase in the amount of land devoted to urban areas between 1982 and 1997 (Alig et al. 2004). The main factors involved in this sharp increase in urbanization were increased population density and personal income. In the United States, urban areas are projected to increase by 79% by 2030, raising the proportion of the total land base which is developed from 5.2% to 9.2% (Alig et al. 2004). Globally, urban areas are forecast to triple between 2000 and 2030 (d'Amour et al. 2017).

BUOWs strongly prefer undisturbed, open grassland habitat with active colonial sciurid populations present. Clayton and Schmutz (1999) found that a loss of grassland habitat with burrows for roosting and nesting is occurring throughout the central Great Plains ecosystem. They concluded that these changes are irreversible on a scale which would be required to help this owl and that this species may face extinction in Canada – the northern limit of its range in North America. Habitat fragmentation was found to be negatively correlated with persistence of breeding BUOWs in Saskatchewan (Warnock 1997). In the United States, even though there is ever-increasing urbanization and land-use changes, BUOWs were found to be able to live in urbanized environments with <40% developed land cover, provided that water and suitable soils are available (Beebe et al. 2014). However, in studying post-fledging survival rates of young owls from greenspace, urban and agricultural sites, Griffin et al. (2017) concluded that programs managing for BUOWs in human-altered landscapes should avoid establishing artificial burrows and translocation sites in greenspace adjacent to urban areas, and, in the southwestern United States, should focus on agricultural areas.

Black-tailed prairie dog and other burrowing mammal population reductions (e.g., control programs, introduced sylvatic plague) have severely impacted BUOW populations in North America (Sheffield 1997*a*; Klute et al. 2003). Prairie dog control programs have

decimated black-tailed prairie dog populations by more than 98% since 1900 (Sheffield 1997*a*). In addition to direct mortality of prairie dogs, epizootics of sylvatic plague have decimated prairie dog populations throughout their North American range.

In addition, carnivore control programs have also led to declines in BUOW populations, albeit through indirect effects. The extirpation of gray wolves and increased tree cover on the North American grasslands have allowed populations of other mammalian and avian predators to increase, most likely to the detriment of BUOW populations (Poulin et al 2011). Further, owls using small, isolated habitat fragments may be more vulnerable to predation by mesopredators (White 1994).

Contaminants (agricultural, rangeland pesticides, etc.) are among the threats to BUOWs. Owls in general, including BUOWs, are known to be sensitive to exposure to pesticides and other contaminants (Sheffield 1997*b;* Gervais and Anthony 2003). Insecticides can be acutely toxic to BUOWs, and rodenticides can cause secondary poisoning through consumption of exposed small mammals (Justice-Allen and Loyd 2017), and both types of pesticides can suppress prey populations and may negatively impact survival of BUOWs (James and Fox 1987; Fox et al. 1989; James et al. 1990; Sheffield 1997*b*).

Another threat which is perhaps more serious as those outlined above is climate change. Using a combination of BBS and CBC data with correlative distribution modeling, Langham et al. (2015) assessed geographic range shifts for North American birds and found that more than half of all species are projected to lose more than 50% of their geographic ranges across three climate change scenarios through the end of the century. In addition to BBS and CBC data, field research has demonstrated that BUOWs are vulnerable to predicted climate change scenarios in which there are increases in the frequency and severity of extreme climatic events. For example, Fisher et al. (2015) found that BUOW annual productivity over a 7-year period varied inversely with breeding season precipitation anomalies, estimating a decrease in mean annual productivity of 12% from 1960-2012. Further, from 1998-2013, Cruz-McDonnell and Wolf (2016) found that the breeding population of BUOWs in Arizona declined 98% (from 52 pairs to 1 pair), and nest success and fledgling output also declined significantly. These trends were strongly associated with the combined effects of decreased precipitation and increased air temperature. The entire breeding process was significantly delayed due to extreme weather conditions, and body masses of all BUOWs were significantly reduced (7.9-20.0%). Thus, climate change resulting in an increasingly warm and dry climate may contribute to the further decline of BUOWs, especially in the arid southwestern United States (Cruz-McDonnell and Wolf 2016).

Finally, any discussion of threats to BUOWs is not complete without including cumulative effects. Cumulative effects of these threats are unknown, but conservatively could be considered additive at a minimum (Hodgson and Halpern 2019).

Conclusions

Overall, BBS data indicate substantial annual BUOW declines in the United States (mainly the northern states, but also some southern states as well) and especially in Canada. The CBC data indicate that, in the United States, BUOWs spend early winter mainly in four states (California, Texas, Arizona, and New Mexico), and overall, numbers are quite low and generally large efforts are needed to find them on CBCs. In Canada, BUOWs are exceedingly rare in winter. The situation with wintering populations of BUOWs in Mexico is becoming somewhat clearer, but more work is really needed.

The peer-reviewed literature from this 20-year interval reveals that population declines have occurred in the United States and Canada, and that in many locations

Table 6 - Western Burrowing Owl (*Athene cunicularia hypugaea*) population status/trends from the literature (1997-2017).

Tabela 6 - Estado/tendência da população de coruja-buraqueira-ocidental (*Athene cunicularia hypugaea*) de acordo com a literatura (1997-2017).

LOCATION	POPULATION STATUS/TREND	REFERENCE
Arizona (USA)	Original state database had 281 burrowing owl locations; in 2001, 164 of those locations surveyed; burrowing owls found at only 29 of these sites, and also 4 new sites; 19% detection; most burrows found along concrete-lined irrigation canals in agricultural areas instead of in prairie dog towns or creosote flats; apparent population decline in the state; burrowing owls not found in 82.3% of original nesting locations.	Brown and Mannan (2002)
California (USA)	Burrowing owl populations declined in Santa Clara and San Francisco areas; 11 years of censuses (1999-2009) available; all 3 populations declining; positive growth rate necessary to lower probability of extinction (population size not enough); reason for decline not specified.	Barclay et al. (2010)
California (USA)	Decline in burrowing owl population attributed to habitat disturbance/loss during expansion of airport; population analysis suggested the key factor was reduction of adult survival.	Barclay et al. (2011)
California (USA)	In San Diego County, 250-300 pairs of burrowing owls found in late 1970s-early 1980s, compared to only 46 pairs in 2007; habitat fragmentation/loss, human disturbance, and vehicle collisions among the main factors involved in the decline; need for immediate management plan for burrowing owls.	Lincer and Bloom (2007)
California (USA)	Reviewed status of the burrowing owl in the greater San Francisco Bay area; historically, the most abundant populations were in Alameda, Contra Costa, and Santa Clara Counties, and that populations were locally abundant within portions of Solano and San Mateo Counties; breeding burrowing owls are extirpated from 4 of 10 area counties (Napa, Marin, San Francisco, and Santa Cruz) and likely extirpated from two others ((sw Solano and San Mateo Counties); burrowing owls are no longer abundant and maybe disappearing entirely from w. Contra Costa, w. Alameda, and Santa Clara Counties; threats for these burrowing owls include habitat loss, current eviction methods (both passive and active), inadequate mitigation practices, pest management, and rodent poisoning; the San Francisco Bay area burrowing owl population has already undergone a substantial decline in abundance and is greatly diminished in extent from its former distribution.	Townsend and Lenihan (2007)
California (USA)	Surveyed the entire breeding range of the burrowing owl in California (except islands); relying on volunteers, 860 5km x 5 km blocks were surveyed and exact locations of 1,758 pairs were documented; using data from randomly-selected blocks, a statewide breeding population of 9,187 pairs was extrapolated; compared results to DeSante et al. (2007) using identical methods and study area boundaries during 1991-1993; our 2006-2007 estimate of 8,128 pairs was 10.9% lower than the previous estimate, but difference was not statistically significant; burrowing owls appear to have declined particularly sharply in two urban areas – San Francisco Bay area and Bakersfield; surveys of previously unsurveyed portions of species range yielded few or no owls in the Modoc Plateau/Great Basin, n. Mojave/e. Sierra Nevada, e. Mojave, and Sonoran Desert regions, but detected relatively large populations in the Palo Verde Valley and the w. Mojave Desert region.	Wilkerson and Siegel (2010)

LOCATION	POPULATION STATUS/TREND	REFERENCE
California (USA)	Systematic surveys for burrowing owls were conducted during the 2006 and 2007 breeding seasons across portions of the state's se deserts which had not previously been surveyed for this species; found few or no burrowing owls in n. or e. portions of the Mojave Desert or in the Sonoran Desert (excluding Palo Verde Valley); however, there was a substantial concentration of burrowing owls in the w. Mojave Desert (estimated up to 560 breeding pairs); also documented 179 breeding pairs of burrowing owls along the banks of water conveyance structures in Palo Verde Valley in the Sonoran Desert region; these two disjunct populations comprise a significant portion of the population of burrowing owls in the entire state.	Wilkerson and Siegel (2011)
Colorado (USA)	Estimated abundance of burrowing owls in three habitats within the Colorado shortgrass prairie ecosystem – prairie dog colonies, grasslands not occupied by prairie dogs, and dryland agriculture; est. 3,554 burrowing owls in e. Colorado; burrowing owl density on prairie dog colonies (3.04 birds/100 ha) was significantly higher than densities in either grassland or dryland agricultural plots; results suggest that increasing prairie dog colonies would positively influence the abundance of burrowing owls.	Tipton et al. (2009)
New Mexico (USA)	Populations of Western Burrowing Owls surveyed through different methodologies; increasing or decreasing depending upon site; loss of suitable habitat responsible for population declines.	Arrowood et al. (2001)
New Mexico (USA)	From 1998-2013, the breeding population of BUOWs on Kirtland Air Force Base in Albuquerque declined 98.1%, from 52 pairs to 1 pair, and nest success and fledgling output also declined significantly; these trends were strongly associated with the combined effects of decreased precipitation and increased air temperatures; all breeding activities were significantly delayed, and body masses of juveniles and adult BUOWs decreased significantly over time; an increasingly warm and dry climate may be contributing to continuing BUOW in the arid sw United States.	Cruz-McDonnell and Wolf (2016)
New Mexico (USA)	Decline of burrowing owls in the Santa Fe area from 68 to 6 pairs (2011) in less than a decade.	Grimason (2016)
North Dakota (USA)	Surveyed historical sites where burrowing owls were most commonly found 15-30 years ago (the Missouri Coteau and adjoining Drift Plain in central and nw North Dakota) and prairie dog colonies in sw North Dakota; burrowing owls were detected at 23-60% of prairie dog towns surveyed during 1994-1999, which was lower than figures reported for burrowing owls at prairie dog colonies across other Great Plains states; e. and n. of the Missouri River, breeding burrowing owls have changed from fairly common or uncommon to rare in the best potential habitat that remains, and have disappeared from the E one-third of the state; populations apparently declined sharply during the past 5-15 years; in sw North Dakota, burrowing owl population trend is unclear but probably tied closely to prairie dog abundance, which may still be declining.	Murphy et al. (2001)
Oklahoma (USA)	Recent survey of black-tailed prairie dog colonies indicated that total colony area in the state continues to decline, decreasing by 4-7% over the past 10 years; estimated 800-1,000 breeding pairs of burrowing owls occur in the state, vast majority of these are relegated to the three panhandle counties (Cimarron, Texas, Beaver); BBS data show significant declines (12.3%/year) in the state; CBC data, although limited, also suggest declining numbers of burrowing owls in the state.	Sheffield and Howery (2001)

LOCATION	POPULATION STATUS/TREND	REFERENCE
Texas (USA)	Analyzed BBS (1966-1999) and CBC (1960-2001) data along with Texas Breeding Bird Atlas (1987-1992) data to construct a distribution map for burrowing owls in Texas (by county); no significant changes found in mean number of burrowing owls during the breeding season, but slope was negative, indicating a population decline; mean number of burrowing owls was consistently low; significant decline seen in mean number of wintering owls; there have not been any large peaks in mean number of burrowing owls recorded since the early 1970s; Lubbock County consistently has reported the highest numbers of owls in winter (average 3-10 owls/count circle).	McIntyre (2004)
Texas (USA)	Burrowing owls found to have declined 6.9% from 1980-2005.	Skrei (2001)
Texas (USA)	Investigated historical range of burrowing owls in s Texas by reviewing accounts of early ornithological collecting expeditions, examining species accounts and reviews, and gathering information from museum specimens collected in Texas; burrowing owls were widespread and relatively abundant in coastal prairies until brushland became the dominant ecosystem in s Texas in the 1890s; clearing of brush for agricultural development in the early 1900s allowed burrowing owls to persist as winter residents in south Texas; burrowing owls extirpated as breeding species by about 1950; status of burrowing owls on managed grasslands of private ranches in s Texas remains unknown.	Woodin et al. (2008)
Washington (USA)	Analyzed North American BBS data using two analytical approaches to determine population trajectory in e Washington; used a mixed model analysis to estimate rate of decline in number of burrowing owls detected between 1968 and 2005; the slope in the number of burrowing owls detected was negative for 12 of the 16 BBS routes in Washington which detected them; numbers of breeding burrowing owls detected in e Washington declined at a rate of 1.5% annually.	Conway and Pardieck (2006)
Wyoming (USA)	Went back and re-sampled historical nesting locations (n=103); only 18% of these were occupied in 1999; surveyed 85 plots selected at random northern mixed- and short-grass prairies; only 1 owl found on random surveys; study highlights the importance of historical nesting sites to burrowing owls in Wyoming.	Korfanta et al. (2001)
Alberta (CAN)	Standardized diurnal call-playback surveys for burrowing owls conducted between 1991-2000 near Hanna, and between 1993-2000 near Brooks; both survey areas are located within the historical breeding distribution of burrowing owls in native mixed-grass prairie habitat; Hanna surveys indicated that density of nests (13.7 nests/100 km^2) declined significantly between 1991 and 2000; the Brooks surveys indicated that the density of nests (8.9 nests/100 km^2), although lower than Hanna, did not decrease during the course of the surveys; the significant decline in Hanna most likely indicative of contraction of the northern edge of the breeding distribution of burrowing owls in Alberta, and suggests that the population will soon become extirpated from that area.	Shyry et al. (2001)
Saskatchewan (CAN)	In 1988, Operation Burrowing Owl members (n=352) reported 681 burrowing owl pairs, considerably more than the 54 burrowing owl pairs reported by Operation Burrowing Owl members (n=459) in 2000; following application of a correction factor, the annual census indicated a 95% decline in estimated numbers of pairs over 13 years from 1988 (1,032 pairs) to 2000 (56 pairs); this represents an average decline of 21.5%/year; by 2000, 94% of all formerly occupied sited had 0 burrowing owls.	Skeel et al. (2001)

where BUOWs formerly were common, they are disappearing at an alarming rate. Returning to conduct surveys at historical nesting sites is very important; efforts to date generally have found that only a small percentage of sites are still occupied. Documented threats to BUOWs are numerous and varied, and range from localized habitat loss, substantial reductions in fossorial mammal populations, pesticides, to range-wide issues of urbanization, agricultural intensification, and climate change.

Long-term databases such as the BBS and CBC, as well as surveying of historic and current breeding sites, and use of citizen science (e.g., eBird, iNaturalist, etc.) should be included as part of a more comprehensive plan to monitor BUOW populations in the face of the above-mentioned continuing threats. The US Fish and Wildlife Service's Birds of Conservation Concern 2003 and 2009 reports both had BUOWs listed nationally, regionally, and in each United States/Canada Bird Conservation Region in which they occur. This denotes the need for upcoming Endangered Species Act (ESA) listing/protection unless immediate and substantial conservation actions are taken on their behalf.

Recommendations

In the United States, evidence for declines in BUOW populations in most locations is strong, and with the substantial number of threats they face, it is now time for serious consideration of BUOWs for national protection under the Endangered Species Act.

States with no protective conservation status for BUOWs (n=7) all have substantially declining populations, and each state should consider providing conservation protection for BUOWs and their habitat.

At the state/provincial level, surveys for BUOWs should also include surveys of prairie dogs and ground squirrels and the extent of their towns, as well as flea populations (vectors for sylvatic plague).

Prairie dog and other colonial sciurid towns are crucial habitat for BUOWs in North America and must be conserved and maintained to preserve ecological integrity of grassland ecosystems.

When plague epizootics eradicate prairie dog towns, recolonization should be encouraged and reintroductions should be conducted in order to maintain towns prior to any potential land-use conversion.

Indirect impacts of prairie dog sylvatic plague on BUOWs may be substantial in some cases and requires further analysis.

Conservation and management measures, education, and changes in both public attitudes and policies are necessary for the continued existence of viable pops of BUOWs and grassland sciurids in North America (see Holroyd et al. 2001).

There is a need to increase the number of BBS routes and CBC count circles for BUOWs in Mexico in order to derive reliable population estimates and trend data in that country.

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