Burrowing Owl Climate Change Adaptation Plan for Alberta

Ryan J. Fisher and Erin M. Bayne
Department of Biological Sciences, University of Alberta, Edmonton AB Canada

Prepared for the Biodiversity Management and Climate Change Adaptation Project

March 31, 2014

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Suggested citation:

Fisher, R.J. and Bayne, E.M. 2014. Burrowing Owl Climate Change Adaptation Plan for Alberta. *Prepared for the Biodiversity Management and Climate Change Adaptation project.* Alberta Biodiversity Monitoring Institute, Edmonton, AB, 58pp.

Corresponding authors:
Ryan Fisher: rjf@ualberta.ca
Erin Bayne: bayne@ualberta.ca

Alberta Biodiversity Monitoring Institute
CW-405 Biological Sciences
University of Alberta
Edmonton, Alberta, Canada T6G 2E9
Phone: (780) 492-6322
E-mail: abmiinfo@ualberta.ca

This report was produced as part of the Biodiversity Management and Climate Change Adaptation Project. This project is led by the Alberta Biodiversity Monitoring Institute, with collaborators from the University of Alberta and the Miistakis Institute. The project receives its core funding from the Climate Change and Emissions Management (CCEMC) Corporation.

Preface

The Alberta Biodiversity Monitoring Institute (ABMI) is an arm's-length, not-for-profit scientific organization. The primary goal of the ABMI is to provide relevant scientific information on the state of Alberta's biodiversity to support natural resource and land-use decision making in the province.

In the course of monitoring terrestrial and wetland ecosystems across the province, the ABMI has assembled a massive biodiversity database, developed reliable measurement protocols, and found innovative ways to summarize complex ecological information.

The ABMI undertakes focused projects to apply this capacity to specific management challenges, and demonstrate the value of the ABMI's long-term monitoring data to addressing these challenges. In some cases, these applied research projects also evaluate potential solutions to pressing management challenges. In doing so, the ABMI has extended its relevance beyond its original vision.

The ABMI continues to be guided by a core set of principles – we are independent, objective, credible, accessible, transparent and relevant.

This report was produced in support of the ABMI's Biodiversity Management and Climate Change Adaptation project, which is developing knowledge and tools to support the management of Alberta's biodiversity in a changing climate. The views, statements, and conclusions expressed in this report are those of the authors and should not be construed as conclusions or opinions of the ABMI.

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This work could not have been completed without cooperation from local landowners, government pasture managers, and regional/provincial biologists. We would like to thank the numerous field assistants, graduate students (specifically, C. Scobie, A. Marsh, and J. Stevens), and collaborators/project leads (Dr. Troy Wellicome [Environment Canada/Canadian Wildlife Service], Ray Poulin [Royal Saskatchewan Museum and University of Regina] and Danielle Todd [University of Regina]) that collected all of the long-term Burrowing Owl field data. Funding for field work and graduate student/post-doctoral fellow support was generously provided by: World Wildlife Fund Canada, Saskatchewan Environment and Resource Management, Foothills, TransGas, TransCanada, and Interprovincial Pipe Lines, Universities of Alberta and Regina, Canadian Wildlife Service/Environment Canada, Bill Shostak, McAffee, Taverner, John K. Cooper, Frank Chapman, Alexander Bergstrom, and Mewaldt-King Awards, Wildlife Preservation Trust Canada, Dennis Pattinson Conservation and Natural Sciences and Engineering Research Council of Canada Scholarships, Canadian Wildlife Federation, Environmental Youth Corps Canada, and Operation Burrowing Owl/Nature Saskatchewan.

We also thank the members of the Biodiversity Management and Climate Change Adaptation Project for feedback on various parts of this project and especially Amy Nixon for providing valuable guidance and support during the writing of this report. C. Scobie provided an excellent in-depth review of a previous version of this report.

Executive Summary

Approximately 60% of Alberta's species of birds, fish and mammals are found within the Grassland Natural Region. Unfortunately, >75% of Alberta's species-at-risk also inhabit this region and these species are facing increased human-development pressures and a changing climate. The Burrowing Owl is one such species that is currently listed as an Endangered species in both Alberta and Canada. This report is intended to provide some adaptation strategies that are focused on management of Burrowing Owls in the face of a changing climate.

The climate envelope of the grassland and parkland regions is expected to expand northward along with the associated vegetation communities. This would present a unique opportunity for potential expansion of the Burrowing Owl range in Alberta. Yet, historical southward range contractions suggest that natural range expansion is an unlikely possibility. Given that newly suitable habitat may be created, but Burrowing Owls are not likely to expand naturally, assisted colonization or reintroductions might be feasible options. Reintroductions into areas further north than the current Burrowing Owl range, but still within the indigenous range would carry the least amount of risk and likely highest chance of success. This would help to increase the geographic distribution of Burrowing Owls so that they are not clustered in one part of the province and these areas may become more suitable from a climate perspective in the future. However, assisted colonization outside the Burrowing Owl indigenous range could also be considered, albeit with higher risks and the potential need for continuing human-intervention to sustain the introduced population.

Our research has shown that past extreme rainfall events: (1) increased the chance that a Burrowing Owl nest will fail completely due to flooding, (2) reduced the number of offspring as a result of starvation, and (3) reduced the chance that a burrow was reused in subsequent breeding seasons. Several adaptation options are presented to manage Burrowing Owls in response to changes in the frequency and intensity of extreme weather. Other management strategies such as construction of artificial burrows and targeting conservation strategies in areas with good drainage in order to prevent burrow flooding would also help to buffer owls against extreme rainfall. Habitat management promoting an accessible and abundant prey source is critical for buffering the effects of extreme rainfall on Burrowing Owls. If Burrowing Owl populations become extremely low, supplemental feeding to help Burrowing Owls during inclement weather could be considered as a stop-gap management action.

The management of Alberta's Burrowing Owls in the face of changes in both average temperature and precipitation conditions, in addition to changes in the frequency and intensity of extreme weather events is feasible. However, management of this species will take a coordinated effort beyond the boundaries of Alberta and Canada.

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1 Introduction

Climate is one of the dominant factors influencing the distribution of Alberta's grasslands (McGinn 2010, Schneider 2013) along with other natural factors such as soils, topography, grazing, and fire frequency. The climate in prairie Canada is characterized by little precipitation and significant temperature variability between seasons. On average, summer maximum and minimum temperatures in prairie Canada exceed those in winter by 22-28°C (McGinn 2010). The Canadian prairies receive an annual average of 454 mm of precipitation, with Alberta grassland regions receiving slightly more annual precipitation (482 mm; McGinn 2010). Approximately 70-80% of yearly precipitation occurs in the months of June and July (McGinn 2010). The grasslands region is characterized by periodic droughts (McGinn 2010) . For example, McGinn (2010) documented 39 slight, 22 moderate, and 6 extreme droughts, as calculated by the Palmer Drought Index, between 1902 and 1990 at Lethbridge, Alberta. While all of these factors influence the current distribution of grasslands in Alberta, <45% of historical native grasslands remain in the province largely due to human land use pressures (Gauthier and Wiken 2003).

In addition to changes in landuse over the last century, Alberta's climate in the grassland region has also been changing. Between 1912 and 2011, Schneider (2013) reported that mean annual temperature at 5 weather stations in southern Alberta increased by 1.11°C and the rate of warming has increased at a pace of 0.29°C per decade since 1970. There have been no detectable changes in mean annual precipitation in Alberta in the last 100 years (Schneider 2013); however, mean annual precipitation is projected to decrease during the summer months under some climate change scenarios (Schneider 2013) . Although there is high uncertainty, projections indicate that while there may be an overall decrease in mean annual precipitation, the rain that does fall may do so in more frequent and higher intensity extreme events (Mladjic et al. 2011).

Approximately 60% of Alberta's species of birds, fish and mammals that are recorded by the Alberta Biodiversity and Monitoring Institute are found within the Grassland Natural Region (Alberta Biodiversity Monitoring Institute 2013). Unfortunately, >75% of Alberta's species-at-risk also inhabit this region and these species are facing increased human-development pressures and the projected changes in climate noted above. These grassland species will either go extinct as a result of these human development pressures or climate changes or a combination of both, or respond to these challenges by adapting *in situ* or by shifting their ranges. The challenge is to understand how society would best respond to these changes in such a way as to protect, maintain and enhance the values and benefits provided by Alberta's biodiversity. To do so, we need a better understanding of how climate change will affect the province's plants and animals.

In this report we will provide adaptation strategies for the Burrowing Owl (*Athene cunicularia*) in the face of a changing future climate in Alberta. The majority of this report will be focused on providing management strategies for Burrowing Owls in response to changes in the frequency and intensity of extreme rainfall events. However, we also provide a review of potential changes in the climate niche of Burrowing Owls in

Alberta and suggest potential management and adaptation strategies in light of these changes.

Throughout this document we will use the framework outlined in Millar et al. (2007) to describe potential adaptation strategies for Alberta's Burrowing Owl population. Millar et al.'s (2007) framework includes three possible adaptation strategies: (1) ***resistance options*** (forestall impacts and protect highly valued resources), (2) ***resilience options*** (improve the capacity of ecosystems/species to return to desired conditions after disturbance, and (3) ***response options*** (facilitate transition of ecosystems/species from current to new conditions). Furthermore, ***priority setting approaches (i.e., triage)*** may also be considered, when appropriate, when a response is required to rapidly changing conditions (Millar et al. 2007).

2 The Burrowing Owl

2.1 Description

The Burrowing Owl is one of the smallest owls in Alberta, standing approximately 20 cm tall and weighing approximately 150 g (Poulin et al. 2011). Adults are primarily brown, with beige spotting on the breast, yellow eyes, and a conspicuous white "eyebrow" (Figure 1). Juveniles are similarly coloured but with a solid buff-coloured chest. Burrowing Owls are also distinguished by their long legs with very short feathers. Males are typically not distinguishable from females; however during the breeding season the male may appear lighter in colour, and can be identified performing his territorial mating call.

Figure 1: A male Burrowing Owl perched atop a fencepost in southern Alberta, Canada. (Photo credit: Janet W. Ng).

2.2 Distribution

The Burrowing Owl has a relatively large breeding distribution in the Americas; ranging from southern Canada through much of the Great Plains in the United States, central and northern Mexico, and in suitable habitat in Central and South America (Poulin et al. 2011). Over the last 30 years, the Burrowing Owl range has generally contracted southward and westward (Figure 2; Poulin et al. 2011), yet there have also be some range expansions in South America (Poulin et al. 2011). The main Canadian breeding population of Burrowing Owls occurs in southeastern Alberta and southern Saskatchewan, with a small breeding population in southwestern Manitoba and a breeding population in British Columbia that is largely maintained through captive breeding (Environment Canada 2012).

2.3 Habitat

The Burrowing Owl prefers treeless, relatively flat landscapes. Most nests in Alberta and Saskatchewan are found in grazed pastures (Wellicome unpubl. data). In other parts of their range Burrowing Owls make use of a variety of vegetation and landuse types, including: annual cropland, golf courses, airport grounds, cemeteries, road allowances and ditches, vacant urban lots, and fairgrounds (Poulin et al. 2011). Burrowing Owls nest in underground burrows dug by other mammals and rarely do any digging themselves other than for the purposes of maintaining or enlarging the burrow. Burrowing Owls are strongly associated with prairie dog (*Cynomys* spp.) colonies throughout much of North America (Desmond et al. 2000). In Canada, the majority of burrows used by Burrowing

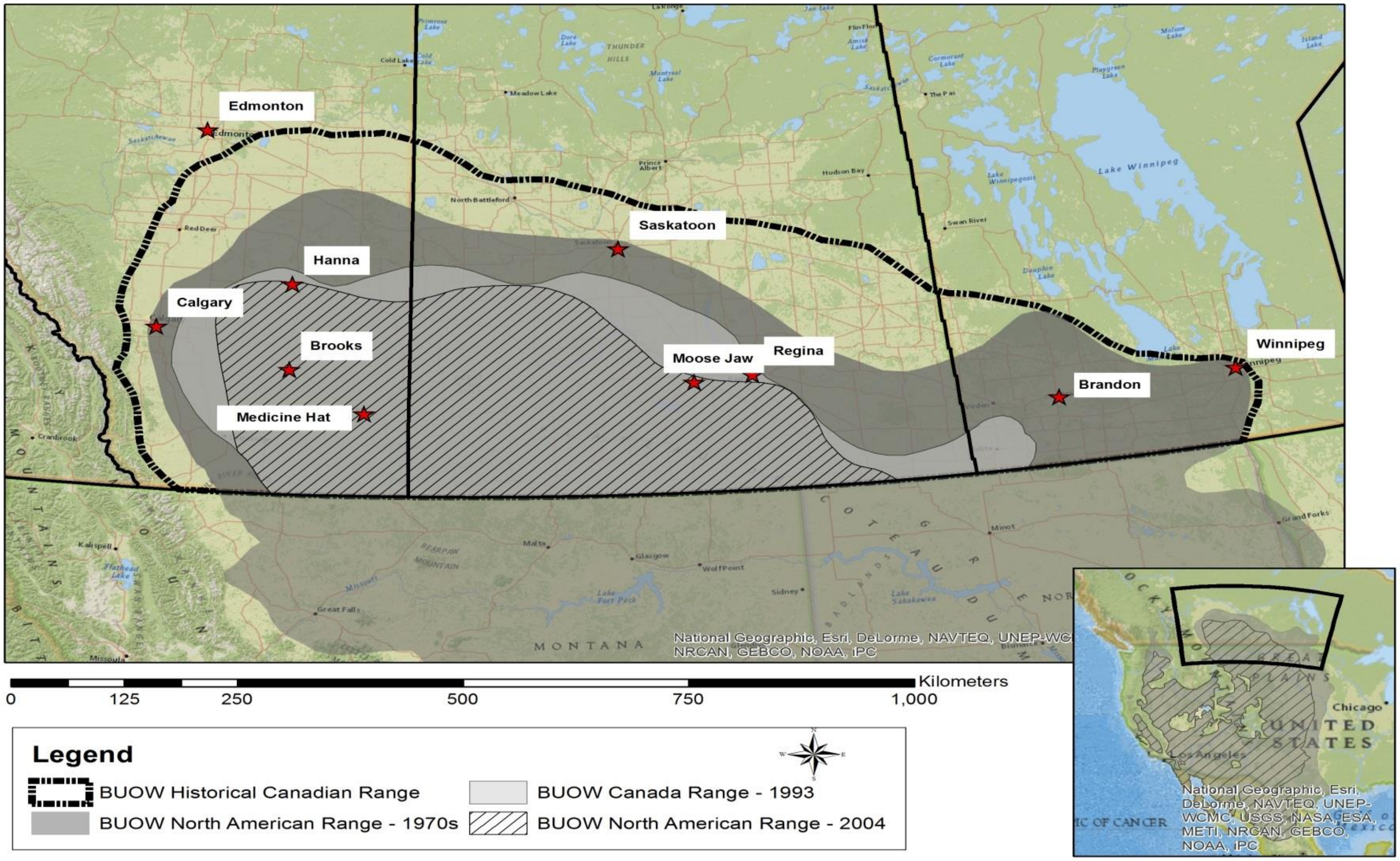

Figure 2: Historical, 1970s, 1993, and 2004 range map of Burrowing Owls in Canada (Adapted from Wellicome and Holroyd (2001)). In the last three decades the Burrowing Owl range has contracted by approximately 36% (Environment Canada 2012).

Owls are dug by American Badgers (*Taxidea taxus*), Richardson's Grounds Squirrels (*Urocitellus richardsonii*), coyotes (*Canis latrans*) and Red Fox (*Vulpes vulpes*; Poulin et al. 2005). The underground nesting chamber allows the nest to remain hidden from predators and the nest contents to be buffered against above-ground environmental conditions. Used burrows usually have a 10-15 cm wide entrance, tunnel lengths of 2-3 m, and a nest cavity typically 25 cm wide and 10-12 cm high (Butts 1973). Burrowing Owls also use other burrows, usually within 250 m of the nest burrow, for caching prey and diurnal roosting (Desmond and Savidge 1999).

Small mammals and insects form a large part of the adult and chick diet on the breeding grounds (Poulin et al. 2011). Primary diet items of Burrowing Owls include deer mice (*Peromyscus maniculatus*), voles (*Microtus pennsylvanicus*, *Lemmiscus curtatus*), and sometimes Richardson's Ground Squirrels (*Urocitellus richardsonii*) birds, reptiles, and amphibians (Poulin et al. 2001, Wellicome 2005). Grasshoppers also form a large part of the adult diet during the breeding season (Poulin et al. 2011)

2.4 Life history

Burrowing Owls in Alberta and Saskatchewan typically arrive on their Canadian breeding grounds in late March and early April (Wellicome unpubl. data). Egg-laying begins shortly thereafter, with the nesting cycle lasting approximately 10 weeks (Scobie et al. 2013).

Burrowing Owls typically lay an average of nine eggs (range 5-14); of these nine eggs, an average of 3-5 chicks survive to fledging age (35 days old; Poulin et al. 2011). Typical sources of chick mortality include starvation (Wellicome et al. 2013) and predation. Once chicks leave the nest their survival rate until migration is approximately

55%, with most mortalities caused by predators and vehicle collisions (Todd et al. 2003). Less than 4% of individuals banded as nestlings in Alberta and Saskatchewan usually return to Canada (Wellicome et al. 2013).

Owls depart on fall migration between September and October (Todd et al. 2003). The migration routes and wintering grounds of Canadian Burrowing Owls are poorly understood despite several attempts to track owls during migration and to locate banded owls in Mexico and the southern United States (Holroyd et al. 2010, Holroyd and Trefry 2011). The information provided by Holroyd et al. (2010) suggests that Canadian Burrowing Owls typically winter in southern Texas, California and northern and central Mexico.

2.5 Current Status

The Burrowing Owl is a federally listed Endangered species in Canada under the *Species-At-Risk Act* (Environment Canada 2012). Because the Burrowing Owl is a federally listed Endangered species, critical habitat, as defined by the federal *Species At Risk Act* (i.e., the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species), must be defined. Critical habitat for Burrowing Owls is only identified in Saskatchewan and is limited to areas within colonies of Black-tailed Prairie dogs (Environment Canada 2012). Once a federal recovery strategy has been developed, as is the case for Burrowing Owls, then an Action Plan summarizing the projects and activities required to meet recovery strategy objectives is then developed. The South of the Divide Multi-Species Action Plan, which is a joint effort between the federal government, local stakeholders, and the Saskatchewan provincial government (Hwang et al. 2013), may also identify more critical habitat, but this would still be limited to the province of Saskatchewan. It should also be noted that burrows, including natural and artificial nesting burrows and satellite burrows, used by Burrowing Owls that are on federal land are also protected from damage or destruction by the *Species At Risk Act*. Burrowing Owls are not protected under the federal *Migratory Birds Convention Act*. Federal recovery goals for this species are stated as: (1) reversing the current population decline and maintaining a self-perpetuating, well distributed population of at least 3000 pairs encompassing the 1993 range of Burrowing Owls in Canada (see Figure 2 for area of 1993 range; Environment Canada 2012).

The Burrowing Owl is also listed as an Endangered species in Alberta under the *Wildlife Act.* This means that it is illegal to kill or harass individuals or disturb their nests at any time of the year on provincial or private land in Alberta. The provincial *Wildlife Act* does not provide legal protection for the habitat of this species; however, some guidelines are in place whereby setback distances and timing restrictions are suggested when conducting disturbances near nests of Burrowing Owls (Government of Alberta 2011). The provincial recovery goal is stated as a long-term population size of 950 pairs, well distributed throughout the 1993 range (see Figure 2 for 1993 range in Alberta; Alberta Environment and Sustainable Resource Development 2012).

Both the federal recovery strategy (Environment Canada 2012) and the Alberta Recovery Plan (Alberta Environment and Sustainable Resource Development 2012) recognize inclement weather as a threat to the Burrowing Owl population.

3. Climate Projections and Distributional Change

Schneider (2013) predicts that the climate envelopes of the Grassland and Parkland region will shift roughly one subregion northward by the 2050s under a "cool" climate scenario. Under a "hot" climate scenario, the Parkland is expected to experience the climate of the Dry Mixed Grassland, whereas the Dry Mixed Grassland will experience the climate of the drier areas of Wyoming and southern Idaho (Schneider 2013). It is expected that vegetation communities associated with hot and dry conditions will increase at the expense of communities associated with cooler and wetter conditions (Schneider 2013). In general, grasslands and parkland will expand northward in Alberta, with boreal forest being replaced by parkland and grasslands. Current Canadian grasslands are likely to be replaced by those grassland types found further south in the Great Plains of the United States (Thorpe 2011, Schneider 2013). Thorpe (2011) also suggested that the following trends will likely occur on the remaining prairie grasslands in Canada: (1) reduced woody encroachment on grasslands, (2) decreases in midgrasses and increases in shortgrass species, (3) C_4 plants may replace C_3 species, and (4) introduction of species from the United States.

Increases in the area of suitable climate for grassland species-at-risk in Alberta could be beneficial for these species, depending on their biology and specific habitat requirements (Thorpe 2011). If the parkland and grassland expand northward and shortgrass species increase, then there should be an increase in the suitable climate, and eventually suitable vegetation composition and structure, for Burrowing Owls. The recent analysis by Shank and Nixon (2013) for the Biodiversity Management and Climate Change Adaptation project suggested that while Burrowing Owls would be susceptible to extreme weather events associated with climate change, owls were predicted to expand their range in Alberta.

However, there are several lines of evidence suggesting that a range expansion of Burrowing Owls is unlikely to occur naturally in Alberta. The historical and current increases in average temperature in southern Alberta described by Schneider (2013) should be amenable to range expansion in this species, but the opposite trend has been observed (Wellicome and Holroyd 2001). Most strikingly is the significant range contraction from north to south and east to west that has occurred in the last several decades at the northern part of the Burrowing Owl range (see Figure 2; COSEWIC 2006). The Burrowing Owl range, as of 2004, covers approximately 37% of their historical range and has likely further contracted since 2004. It is also worthy of note that other avian grassland species-at-risk (Ferruginous Hawk, Sprague's Pipit, Chestnut-collared Longspur, Greater Sage-Grouse) have also experienced a similar southward range contractions and so it is not a unique phenomenon for Burrowing Owls. Range-wide declines of these, and other grassland-associated species (Vickery et al. 2000) may result in the contraction of ranges to core areas where population sizes are larger. Unfortunately, the ultimate causes of these range contractions are as yet unclear.

3.1 Assisted Colonization – A Response Option

If Burrowing Owls are unlikely to expand their range naturally, but the vegetation and suitable climate envelope of Burrowing Owls is likely to expand northward then a unique opportunity for a response option may be possible. Reintroductions of owls back into former unoccupied parts of the historical Burrowing Owl range, or introductions into areas where new suitable habitat becomes available as a result of climate change could be a feasible adaptation option. Recently the IUCN has released comprehensive guidelines on "*Assisted colonization*" (IUCN/SSC 2013). The IUCN/SSC (2013), indicates that translocations of organisms outside their indigenous range carries "potentially high risks that are often difficult or impossible to predict …[and] requires a high level of confidence over the organisms' performance after release, including over the long-term, with reassurance on its acceptability from the perspective of the release area's ecology, and the social and economic interests of its human communities". While the introduction of Burrowing Owls into areas that were not formerly part of their indigenous range carries large risks, reintroductions into areas that were once occupied may be a more palatable option. ***However, and it cannot be stressed enough, until limiting factors for the Canadian Burrowing Owl population are deduced and appropriately managed then reintroductions in any portion inside or outside the Burrowing Owl range may fail without substantial human investment and intervention.***

The following section will identify previous and current Burrowing Owl reintroduction programs, their successes and failures, and will identify some potential risks associated with Burrowing Owl reintroductions in areas outside their indigenous range in Alberta (IUCN/SSC 2013).

3.1.1 Other Burrowing Owl Reintroduction Programs

The Burrowing Owl Conservation Society of British Columbia has implemented a reintroduction program since 1992 and has seen continued increases in the number of owls that return per owl released and concurrent increases in nesting success (Mitchell et al. 2011 and http://www.burrowingowlbc.org/, Accessed January 29, 2014).

Accomplishing a high return rate of reintroduced owls and high nesting success involves a combination of intensive captive breeding (i.e., husbandry), soft-releases, construction of artificial nesting burrows, and intensive monitoring. While the Burrowing Owl reintroduction program in British Columbia has been successful at increasing nesting productivity, the program requires continued human-intervention and installation of artificial burrows because there are generally few available suitable nesting burrows for owls in this region due to low densities of burrowing mammals (Franken et al. 2003). The successes of this British Columbia project can be instructive as to how Alberta may go about initiating a captive breeding and release program for Burrowing Owls but it also demonstrates how long-term of a commitment Burrowing Owl releases may be.

Manitoba is also beginning a Burrowing Owl reintroduction program in areas where owls once bred successfully (http://www.mborp.ca/, Accessed January 29, 2014). It is unclear where, when or what techniques will be used in the Manitoba reintroduction program, as the program is in its infancy.

Reintroduction efforts in the United States have been less successful. Minnesota and Oklahoma have attempted Burrowing Owl reintroduction programs; however, both programs were unsuccessful and abandoned (Klute et al. 2003). In Minnesota, young owls that were released never returned to the reintroduction area in subsequent years to breed (Martell et al. 2001). There is no available information on the Oklahoma reintroduction program.

It is clear that the British Columbia model could be a useful prototype for Burrowing Owl reintroductions in Alberta. While the goal of this paper is not to provide specific details regarding how to design a captive-breeding and reintroduction program for Burrowing Owls, a summary of costs per owl of the initial stages of the Manitoba program is provided in Appendix 1. The rest of this section will identify potential areas for Burrowing Owl reintroductions outside their indigenous range, and identify potential risks associated with reintroductions of Burrowing Owls outside their indigenous range.

3.1.2 Potential areas for Burrowing Owl reintroductions

We used climate envelope models described in Schneider (2013) to identify potential locations where Burrowing Owl assisted colonization could take place in the future should other underlying conditions such as vegetation structure and composition, soils, prey base, and nest availability become suitable for Burrowing Owls (see section 3.1.3; Figure 3). In these figures the yellow and green areas are predicted to contain climates associated with the grassland and parkland regions and would likely be amenable to Burrowing Owl assisted colonization (Figure 3). Further modelling of vegetation response to climate change and subsequent changes in vegetation communities would help to determine areas that would be suitable for Burrowing Owl introductions outside their indigenous range (Thorpe 2012b). Immediate (i.e., within the next few years) reintroductions could be considered north of the current Burrowing Owl range but within their historical range (Figure 3) at or near sites that were once inhabited.

3.1.3 Risks of Assisted Colonization Outside the Burrowing Owl Indigenous Range

1. **Risk to source population** – Populations of owls within the *hypugaea* subspecies (the subspecies of Burrowing Owls in Canada) are essentially panmictic (Korfanta et al. 2005) and so conceivably source Burrowing Owls for the reintroductions could come

from the United States if Canadian birds are not available or are deemed too "at-risk" to be used as a source population. It should be noted that in the early years of the British Columbia reintroduction program, owls from Washington State were used. There is also precedence in Alberta for translocating birds from the United States to Canada. Recently, approximately 40 Greater Sage-Grouse (*Centrocercus urophasianus urophasianus*) were translocated from Montana to Alberta (Alberta Environment and Sustainable Resource Development 2013), suggesting that the province may view this option as feasible and protocols would be in place for this type of activity.

2. **Ecological Risk** - Burrowing Owls rely on a few specific prey species (deer mice, voles, and grasshoppers) in Canada. Both deer mice and meadow voles are already present substantially further north than the historical Burrowing Owl range (Banfield 1974). However, in order to avoid feeding Burrowing Owls indefinitely after reintroduction, the reintroduction program would first need to identify whether a suitable prey base is available and, perhaps more importantly, accessible to the owls (See section 4.3.1 Habitat Management below; Marsh 2012 , Marsh et al. In Press). Given that these reintroductions would be occurring in areas outside of the historical range of Burrowing Owls, an adaptive management approach would need to be implemented to determine best management practices for creating suitable foraging and nesting habitat for Burrowing Owls.

To avoid continuing human intervention to create suitable nesting burrows (i.e., artificial nesting burrows), suitable reintroduction areas would also require burrowing mammals (Richardson's Ground Squirrels or American Badgers) to create suitably-sized

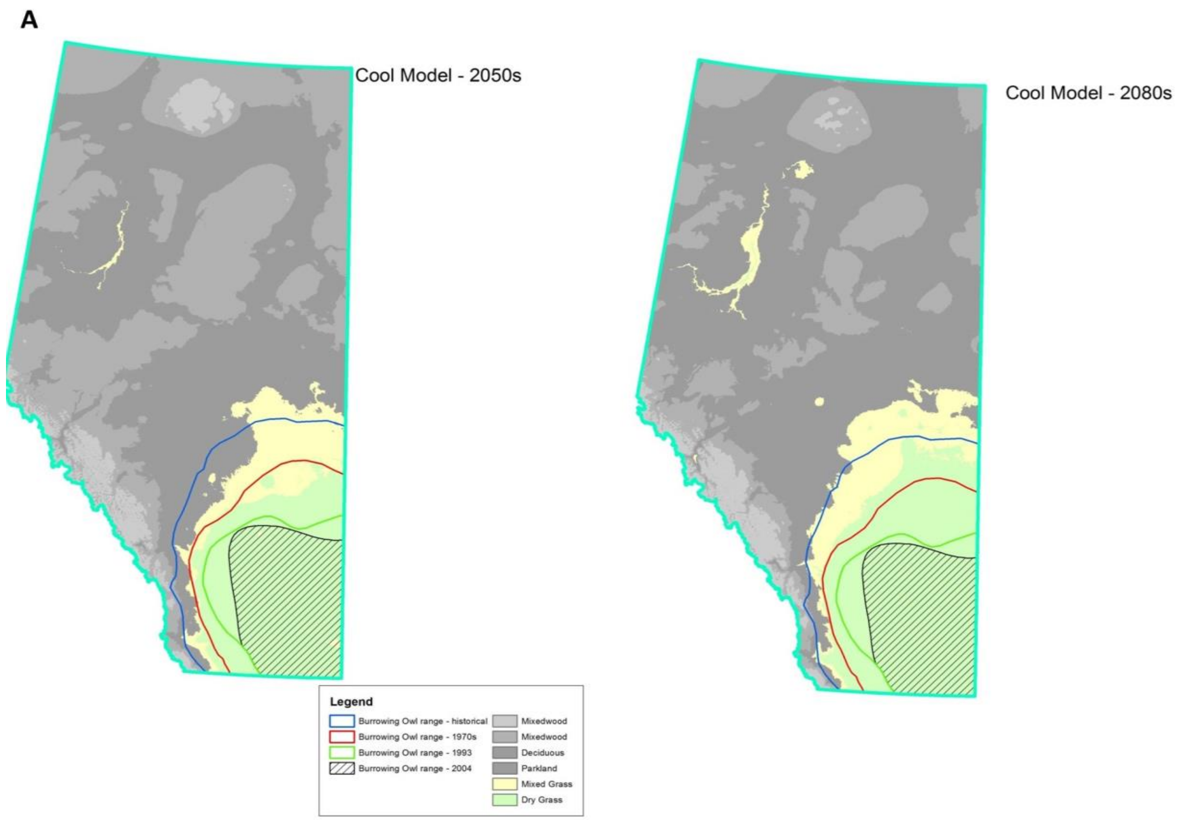

Figure 3 Expected changes (A: Cool Model; B: Dry Model; C: Hot Model; D: Median Model) to Alberta's natural subregions (Schneider 2013) in relation to the historical and current Burrowing Owl range in Canada. Areas for assisted colonization outside of the indigenous range of Burrowing Owls could be considered north of the blue range line in areas that are represented by light green and yellow (i.e., Mixed and dry grasslands). Reintroductions could be considered north of the current range (hatched area) but within the historical range (blue line). Grey areas would likely contain unsuitable climate and habitat for Burrowing Owls.

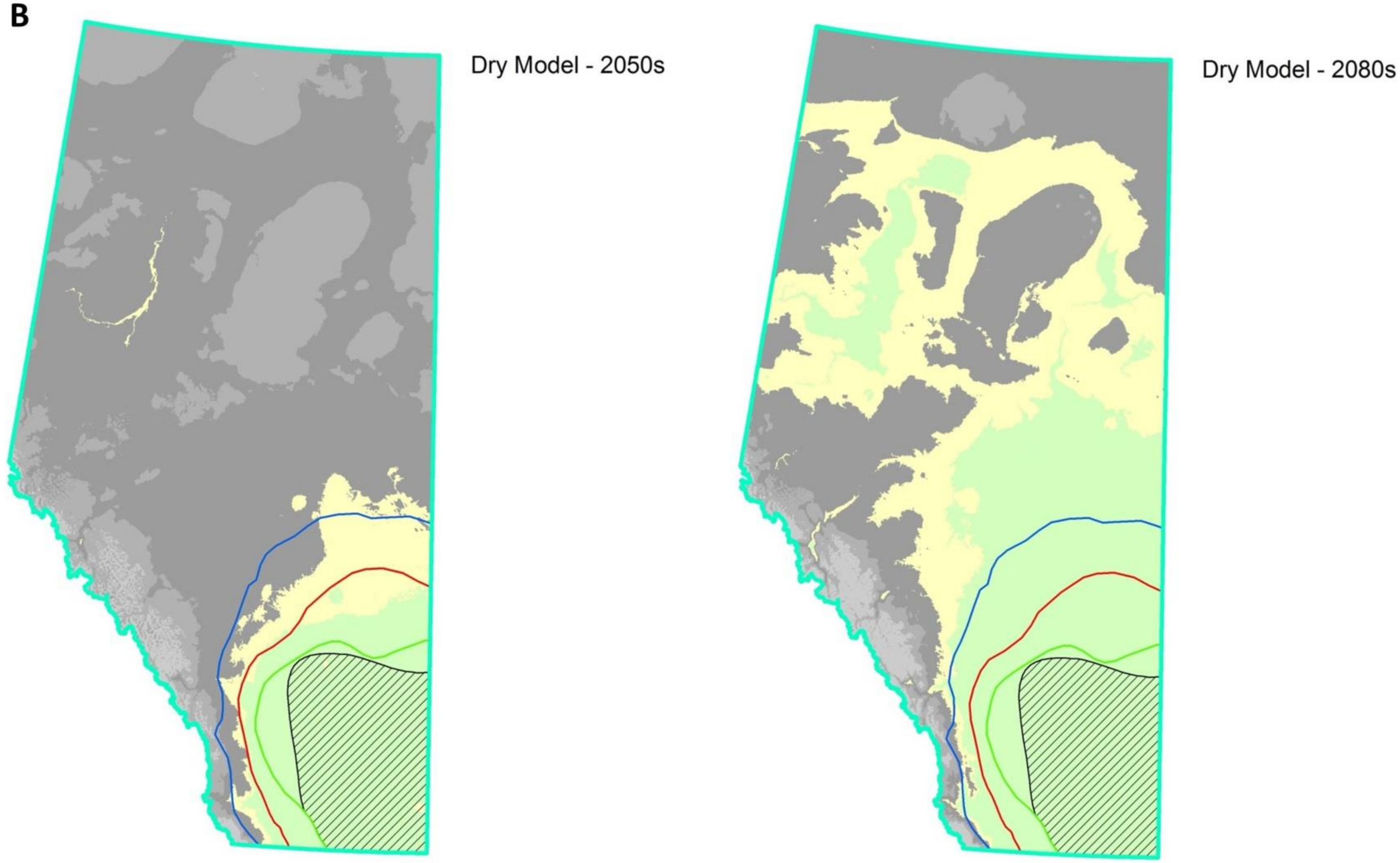

Figure 3 (con't)

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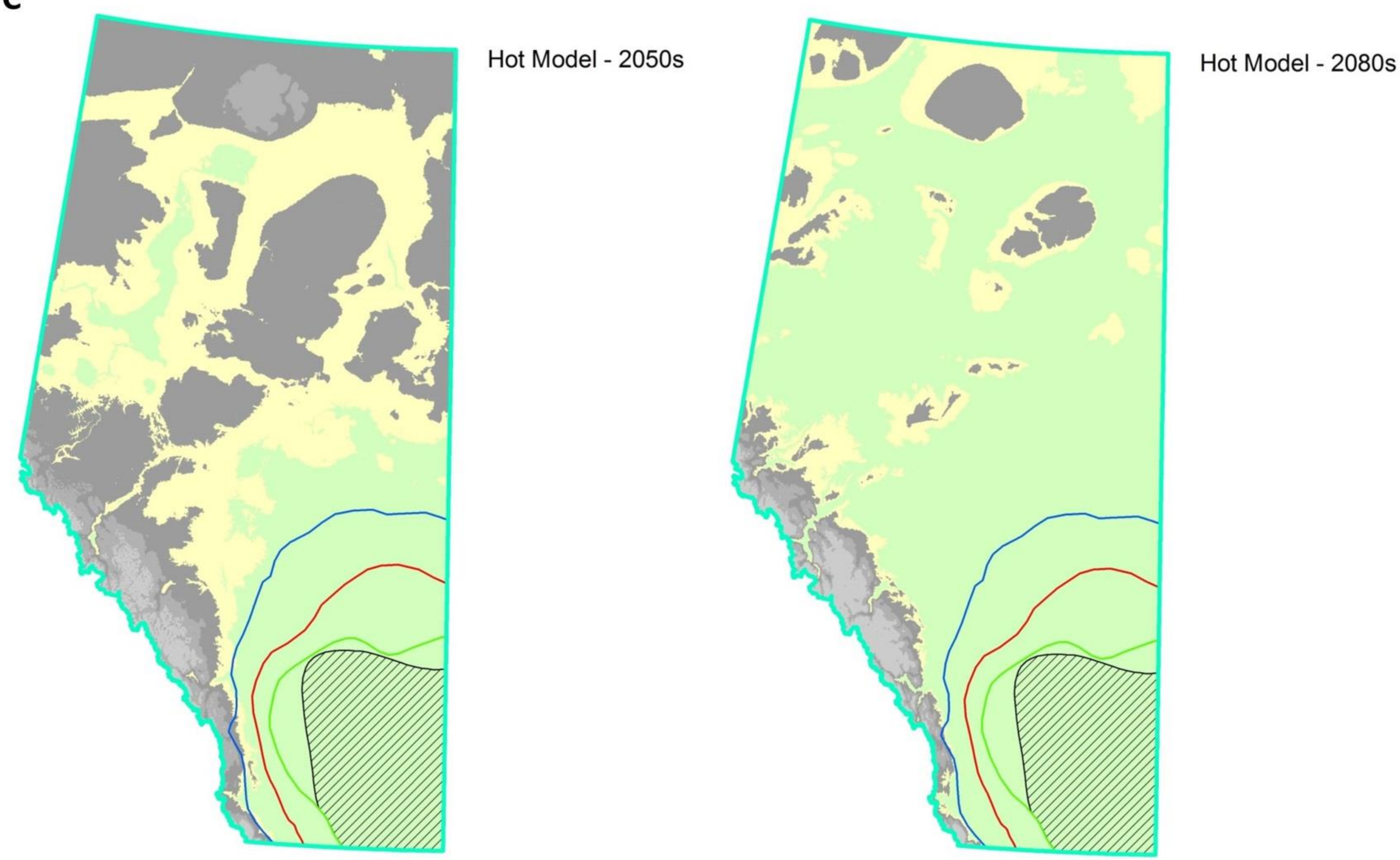

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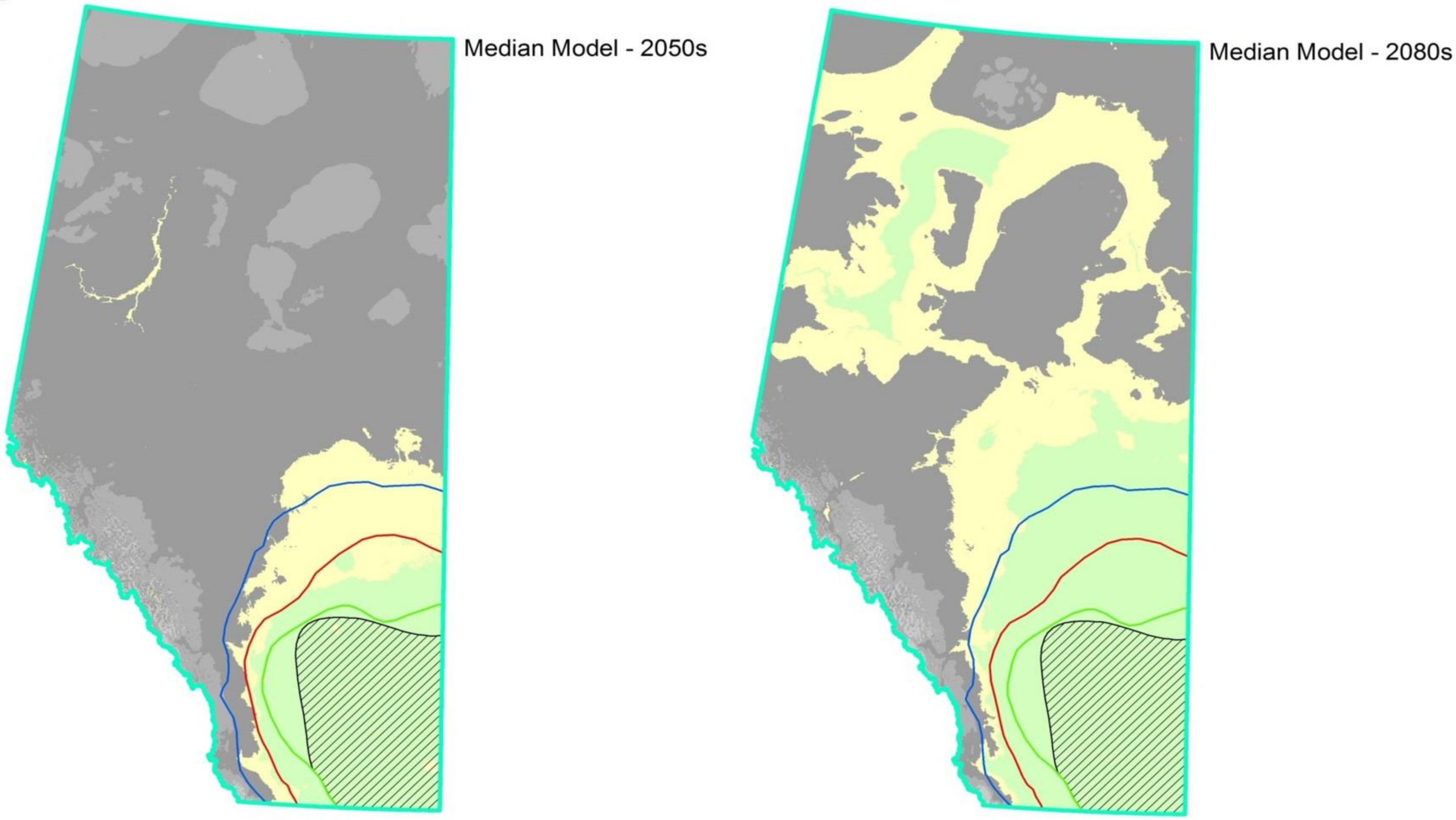

Figure 3 (con’t)

nesting burrows. If the grassland and parkland regions do expand northward, it is conceivable that these highly-mobile burrowing mammals would also expand northward. Unfortunately there is little information on how these “burrow engineers” will respond to climate change. Alternatively, some proposals for Burrowing Owl reintroductions in the United States and Canada go so far as to propose simultaneous reintroduction of burrowing mammals (Leupin et al. 2000, Swaisgood et al. 2011). However, it is highly unlikely that the farming or ranching community would support reintroduction of what are typically considered “pest” species (e.g., Fox-Parrish 2002). Therefore, intensive prey and burrow engineer surveys would need to be conducted to ensure that the reintroduction area could support a self-sustaining Burrowing Owl population (Leupin et al. 2000). It is important to note that the ranges of many of the burrowing mammals already lie further north than the current Burrowing Owl range (Banfield 1974), indicating that reintroductions in these areas would be immediately suitable for Burrowing Owls.

The predator community in these areas would likely be similar to that currently and historical experienced by Burrowing Owls. However, there would be a need to quantify predator densities and predation risk in any sites that are selected for reintroduction.

3. Socio-Economic Risks – There appear to be very few economic or financial risks for stakeholders that may live or do business in areas that would be good candidates for Burrowing Owl reintroductions. However, perceptions of private landowners regarding management of species-at-risk may be an obstacle when attempting to identify suitable locations for reintroductions. Unfortunately, many landowners fear the “strong arm of the law” that may be applied through the *Species-At-Risk-Act* (Henderson et al. 2014).

Currently both artificial and natural residences (i.e., burrows) of Burrowing Owls are protected by the *Species-At-Risk-Act* on federal land. Alberta's *Wildlife Act* would also protect an individual owl and their nest from wilful molestation, disturbance, or destruction. Therefore, any newly created artificial nest burrows would automatically be afforded protection under the *Species-At-Risk-Act* if on federal land and protection under the *Wildlife Act* in Alberta. And so, acquiring landowner consent and cooperation to reintroduce a provincially and federally Endangered Species on their property may be difficult.

3.1.4 Risks of a Reintroduction Program within the Burrowing Owl Indigenous Range

Because Burrowing Owls formerly occupied a substantially larger area further north than their current range (Figure 2), the risks of reintroducing owls back into this area are negligible. The only consistent risk is likely landowner cooperation (see section 3.1.3 above) and political will to conduct this project. Risks of continued human-intervention during reintroductions may also be high if reasons for current population declines are not halted and reversed. Currently, the clustered and clumped distribution of Burrowing Owls and their small population size makes them vulnerable to one or two extreme events that may disproportionately affect a large proportion of Alberta owls. Widening the geographic distribution of Burrowing Owls in newly created suitable habitat within their historical range could help provide some insurance that the majority of owls would not succumb to a large extreme event covering much of their current range.

3.1.5 Summary of Reintroduction Response Option

Reintroduction or assisted colonization of Burrowing Owls are feasible options given that other Burrowing Owl reintroduction programs are already occurring and have been successful in Canada. However, ecological risks and the potential need for continued human-intervention associated with assisted colonization of Burrowing Owls outside of their indigenous range are high. A more palatable option may be to reintroduce owls north of their current range, but still within their indigenous range (e.g., north of the 2004 range but south of the 1993 or historical range; Figure 2). Costs of this response option would be high (Appendix 1) and would need both public and/or political will to make this a successful climate change adaptation strategy. ***However, and it cannot be stressed enough, until limiting factors and reasons for range contractions of the Canadian Burrowing Owl population are deduced and appropriately managed then reintroductions in any portion inside or outside the Burrowing Owl range may fail.***

4. Changes in the frequency and intensity of extreme weather

4.1 Climate Change and Extreme Weather

Historical analyses indicate that the heaviest precipitation events in the United States have increased between 10-20% across much of the Burrowing Owl range in the past 50 years, while projections indicate future increases of 15-40% of the heaviest rainfall events (Karl et al. 2009). Analyses examining historical trends (1950-1995) in daily precipitation in Canadian prairies (within the Burrowing Owl range) suggest that the heaviest precipitation events may have increased in May- July (Stone et al. 2000). However, the most biologically relevant analysis for Burrowing Owls in southwestern Canada showed that the number of daily precipitation events releasing ≥25 mm of rainfall have been decreasing between 1905-1995 (Akinremi et al. 1999). Unfortunately, many trend analyses of daily precipitation in Canada were completed before the 2000s and since then 2002, 2005, 2010, and 2011 have been ranked 5th, 4th, 2nd, and 10th, respectively, of the wettest summers on record in prairie Canada since 1948 (Environment Canada 2013). Future projections for the Canadian prairies indicate between a 5-12% increase in 20-yr return rates of 1-7-day precipitation extremes (Mladjic et al. 2011). Similar increases of 3-4% and 10% for 50- and 100-yr return levels, respectively, are also predicted for prairie Canada (Mladjic et al. 2011). Relatively short-duration (i.e., 2-3 day) extreme rainfall events may also increase in the future (Janssen et al. 2014). Given that Burrowing Owl breeding sites tend to be clustered within the current range shown in Figure 2, local-scale weather patterns and changes in those patterns due to climate could disproportionately affect a large number of Burrowing Owls in Alberta.

4.2 Precipitation Effects on Burrowing Owls

Nest survival of Burrowing Owls decreases during 1-d extreme precipitation events and nest flooding is one of the largest sources of nest loss for Burrowing Owls in Canada (Fisher et al. unpubl. data; Appendix 4). Flooded burrows also have a significantly lower reoccupancy rate (~7%) compared to nests that were successful, although reoccupancy rates of flooded and depredated nests are statistically similar. Flooding can also cause extensive damage to nesting burrows rendering them unuseable in subsequent breeding seasons (Fisher et al. unpubl. data; Appendix 4). Lastly, not only can extreme precipitation cause complete nesting failure, even small amounts of precipitation can cause some of the owlets in a nest to perish (Fisher et al. unpubl. data; Appendix 4).

Using an experiment where we supplementally fed Burrowing Owls during the breeding season, we showed that almost all owlets receiving supplemental feeding survived bouts of inclement weather (Fisher et al. unpubl. data; Appendix 4). Whereas the youngest owlets in broods that did not receive supplemental feeding experienced significantly higher mortality rates than their older nest mates and compared to similarly aged owlets in broods that received supplemental feeding (Fisher et al. unpubl. data; Appendix 4). The results of this experiment showed that the ability of parent owls to bring back adequate food for their brood during bouts of inclement weather is compromised. Whether this is due to reduced hunting efficiency or the inability to hunt remains to be determined. While these negative effects of precipitation on nestling survival can occur in non-extreme conditions (prolonged light precipitation), starvation can also occur under relatively short-duration extreme conditions. Thus, precipitation appears to cause reduced Burrowing Owl reproductive output in two ways: (1) nest flooding under extreme rainfall and (2) starvation during bouts of much less precipitation.

Despite conflicting evidence on historical changes in daily precipitation during the breeding season in Canada (Vincent and Mekis 2006), we suspect that the owl's susceptibility to extreme precipitation is not limited to our study area, as other studies on Burrowing Owls in their core range have reported burrow flooding (MacCracken et al. 1985, Millsap and Bear 2000, Griebel et al. 2007) and reductions in owlet body condition (Griebel and Savage 2003) and survival (Haley 2002) after inclement weather. It is likely that the threshold of daily precipitation causing nest failure due to flooding or reductions in owlet survival will differ across the owls' range; however, range-wide increases in extreme precipitation could have significant influences on the Canadian Burrowing Owl population considering the large number of new breeders that immigrate to Canada from the United States. Any future increases in the frequency of daily precipitation events above 30 mm in Alberta would have a detrimental effect on Burrowing Owl reproductive output and subsequent burrow availability.

The following sections will provide some resistance, resilience, and response options in the face of increasing frequency and intensity of extreme rainfall events for managing the Burrowing Owl breeding population in Canada.

4.3 Resistance and Resilience Options – Forestalling and Promoting Resilience to Impacts

4.3.1 Habitat Management

As noted above, Burrowing Owls that were supplementally fed were able to withstand inclement weather and produced significantly more offspring compared to owls that were not supplementally fed. Supplemental feeding programs may be effective as a stop-gap measure (see below); however, ensuring that Burrowing Owls have an adequate and accessible food supply during the breeding season would promote both resistance and resilience to future changes in the frequency and intensity of extreme weather.

Burrowing Owls forage in a variety of landcover types (native grasslands, tame grasslands, roadside ditches, cropland, and several other habitat types; Marsh et al. 2014) and their home-range selection is not linked to size of grassland patch, amount of grassland in the surrounding landscape, nor amount of habitat fragmentation (Stevens et al. 2011). Although the majority of Burrowing Owls nests in Canada are found on native, grazed grasslands likely because of a high availability of suitable nesting burrows, Burrowing Owls are by no means limited to breeding in native grasslands in much of their breeding range (York et al. 2002, Catlin et al. 2006). These factors indicate that conservation or protection of one habitat type may not be the most efficient strategy to promote resistance or resilience of a generalist species such as the Burrowing Owls to climate change. Typical climate change resistance and resilience adaptation options such as increasing the size and number of protected areas or increasing habitat connectivity may not be suitable for this habitat generalist (Heller and Zavaleta 2009). More specifically, a variety of landuses and landcover types in the landscape appears to be appropriate for this species' breeding and foraging needs (Stevens et al. 2011). Marsh (2012) suggested that management promoting heterogeneous fields with patches of tall and dense vegetation that allows small mammals to thrive and short and sparse vegetation allowing owls to capture prey and nest in would be ideal. Such management strategies could take place in various field types, but some specific suggestions provided by Marsh (2012) are as follows:

1. Promote heterogeneous grazing by livestock, ensuring patches that are heavily grazed for both nesting and successful foraging and patches that are lightly to moderately grazed to allow small mammals to thrive.
2. Leave narrow strips in cropland as stubble to promote vegetation height and density heterogeneity.
3. Leave narrow strips in hayfields that are not mown each year to promote some degree of cover for small mammals while leaving open areas for owls to forage.

These management strategies will likely have to take place in an adaptive-management context, especially under predicted changes to vegetation communities under future climate change scenarios. For example, if there is an increase in short-grass species (Thorpe 2011), then grazing or mowing practices may have to be altered to promote increased plant height (deferred or lighter grazing, reduced herds, change in livestock species, or mowing at different times of the year; Thorpe 2012a).

Alberta's MULTISAR program has developed a suite of Best Management Practices (BMPs) for burrowing animals, Burrowing Owls included. Some general BMPs for maintaining burrowing mammals and Burrowing Owls include: (1) maintaining native prairie, (2) protecting active and historical nest burrows, (3) avoiding the killing of Richardson's Ground Squirrels around active nest sites, (4) removing low yielding land from cropland production and reseeding to native or tame grasses, (5) create variability in grass and litter heights in pastures, (6) avoid high stocking rates resulting in uniform short grass, and (7) leave strips of vegetation in tame pastures when swathing hay. Strategies #1 and #4 may help to maintain suitable nesting habitat, although the utility of these strategies for improving foraging habitat remains to be determined. Strategy #3 would help to maintain the availability of suitable nesting burrows if nesting availability begins to decline due to damage from increased frequency and intensity of storms. Strategies 5-7 align well with suggestions provided by Marsh et al. (2012).

4.3.2 Concentrate habitat conservation measures in areas with "good soil"

Burrowing Owls in Alberta typically select for coarse-textured and sandy soils and avoid finer, clay-like soils (Stevens et al. 2011). These coarse-textured and sandy soils may allow for better drainage during floods (MacCracken et al. 1985). Our analysis examined whether soil types exacerbated or buffered Burrowing Owl burrows from flooding; however, we could find no effects of soil texture or type on daily nest survival (Fisher et al. unpubl. data; Appendix 4). However, our analyses on soil type and texture were at a necessarily coarse scale, but it is likely that local variation in soil type or texture influences a burrow's susceptibility to flooding. Stevens et al. (2011) identified areas of high Burrowing Owl habitat suitability based on coarse-textured and sandy soils (Figure 4). We present the information provided by Stevens et al. (2011) and suggest that current conservation measures be concentrated in these areas. If extreme rainfall events do increase in frequency and intensity, nests in highly suitable habitat would be buffered against some of the effects of extreme rainfall. Further modelling in areas further north than the historic Burrowing Owl range would be beneficial to plan sites for assisted colonizations.

4.3.3 Construction of artificial nest boxes

As mentioned in Section 4.2, the reoccupancy rate of flooded nest burrows is extremely low (~7%) and flooding can cause irreparable damage to natural burrows. Burrow availability does not appear to be a limiting factor for Burrowing Owls in Canada (COSEWIC 2006) and so this adaptation strategy would likely not be appropriate if it is used strictly as a means to increase owl numbers through burrow augmentation (e.g., Barclay et al. 2011). However, providing artificial nest burrows for Burrowing Owls in parts of their current range in Alberta could help to buffer owls against increased chances of burrow flooding and damage of nesting burrows. Artificial burrows with predator proofing also have the added benefit of decreasing nest failure due to predation (Wellicome et al. 1997).

In prairie Canada, artificial nest burrows have typically been installed to replace burrows that were being used by Burrowing Owls (i.e., the natural burrow is excavated

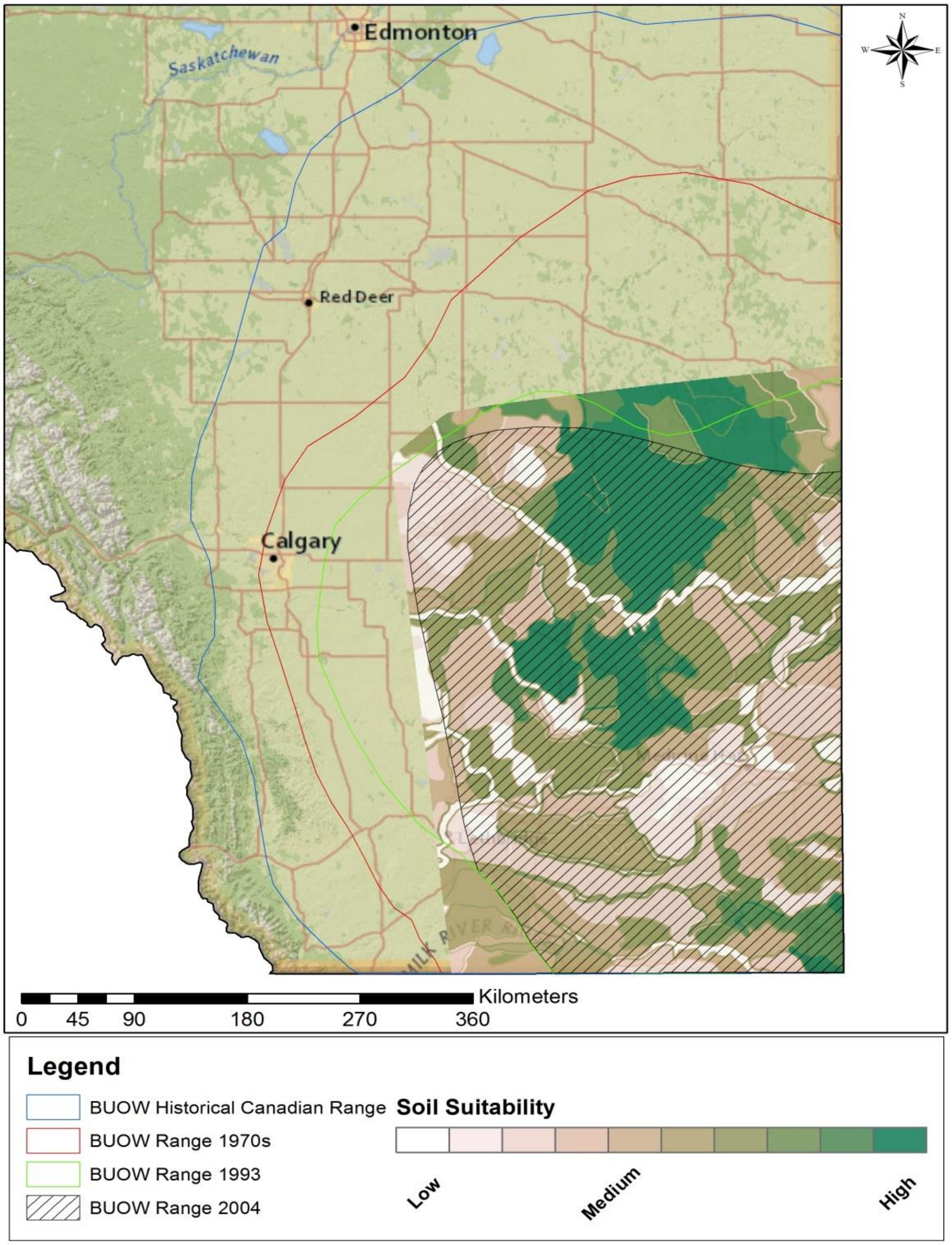

Figure 4 Habitat suitability map by Stevens et al. (2011) showing areas with good soils (green) for Burrowing Owls. These highly suitable areas contain soils that would provide proper drainage in order to buffer Burrowing Owls against extreme rainfall.

and replaced with an artificial burrow). However, in the United States (Trulio 1995, Smith et al. 2005, Barclay et al. 2011) and in British Columbia (Leupin et al. 2000), artificial burrows are usually newly constructed in areas where a natural nesting burrow was not present. In the future, it may not be feasible to convert occupied burrows into artificial burrows, either because there may be very few remaining occupied burrows or because of an unwillingness to disturb natural nest sites. If it is decided that the risks may be too high (e.g., abandonment, nest destruction) to convert natural burrows into artificial burrows, then the following site choices would likely be most effective at attracting owls: (1) construction of new artificial burrows in areas close to nesting owls and with an already high concentration of burrows (Poulin et al. 2005), (2) in areas of high Burrowing Owl habitat suitability (also see section 4.3.2; Stevens et al. 2011), and (3) burrows that were used in the previous 2 or 3 years as these have a small probability of being reused in subsequent years (Fisher et al. unpubl. data).

Construction of artificial burrows should follow the guidelines presented in Johnson et al. (2013). We would add that in order to maximize flood prevention a “rise” in elevation of the artificial tunnel before the nest chamber needs to be included during all installations in the future (Johnson et al. 2013). Furthermore, site selection for any new artificial burrow needs to consider local topography and select areas for construction that are slightly elevated compared to the surroundings. Completion of LiDAR based surveys by the province in the prairie region would be of significant value in predicting where such areas could be most effectively placed.

One key component of artificial burrow construction for Burrowing Owls is continued maintenance of these structures (Belthoff and Smith 2003). Construction of artificial nesting burrows is not a one-time action, but requires continued maintenance in the spring and fall to repair any overwinter or breeding-season damage (Barclay et al. 2011). With maintenance and upkeep, the likelihood of reoccupancy may continue to be high over several years (Belthoff and Smith 2003). An estimate of costs of artificial burrow installation and maintenance is provided in Appendix 2.

4.4 Triage option – Supplemental feeding

Burrowing Owls that are supplementally fed are able to withstand inclement weather and produce significantly more offspring compared to broods that are not supplementally fed (Fisher et al. unpubl. data; Appendix 4). If the frequency and intensity of extreme weather is expected to increase, then supplemental feeding could be considered as a short-term, triage adaptation option. Supplemental feeding should not supplant other management activities to enhance or create suitable foraging and small mammal habitat (Section 3). Furthermore, it should be noted that the Burrowing Owl National Recovery Team (composed of Federal and provincial Species-At-Risk biologists and non-government organizations) in 2013 recommended that supplemental feeding could not be implemented at a sufficient scale (i.e., supplemental feeding would have to take place across Canada and in the northern United States) to be used as a conservation tool for stabilizing or increasing the Canadian Burrowing Owl population. Additionally, previous large-scale attempts at supplemental feeding and predator-proofing nest burrows in Saskatchewan did not prove effective at increasing nor stabilizing the local Burrowing Owl population (Wellicome et al. 1997). Thus, the following recommendations must be placed into context of the above National Recovery Team recommendation.

Supplemental feeding should only be used and considered as a stop-gap measure for conservation of Burrowing Owls in Canada. If populations reach critically low levels, such that major storms could affect a disproportionately large number of remaining individuals, and we start to see a significant increase in extreme rainfall events, then supplemental feeding may be useful. The experimental feeding rates of 255 g food every third day (Fisher et al. unpubl. data; Appendix 4) almost guaranteed that all owlets were able to survive periods of inclement weather. However, for supplemental feeding to be effective it must occur during inclement weather, which is typically the most difficult time for researchers to access nests. Furthermore, when nests occur on private land, landowner permission must be granted to access and provide food to nests. A breakdown of potential costs associated with supplementally feeding owls is presented in Appendix 3.

4.5 Summary of Adaptation Options in Response to Extreme Weather

Habitat management that results in successful Burrowing Owl foraging and supports the prey that they rely on appears critical in order to buffer Burrowing Owls against future changes in extreme rainfall. Artificial burrow construction or conservation of currently active Burrowing Owl nests could be done in areas with soils that drain well during floods in order to promote resilience in the Burrowing Owl population to extreme rainfall. More human-intensive management scenarios include constructing artificial burrows to prevent flooding and potentially supplemental feeding if population sizes become very low. It is clear that management of Burrowing Owls in the face of increases in the frequency and intensity of extreme rainfall will require coordination amongst private landowners, industry, non-government organizations, and all levels of government.

5. Knowledge Gaps

5.1 Factors influencing Burrowing Owls outside the Canadian breeding grounds

Factors outside the Canadian breeding grounds (migration and wintering grounds) may have an important influence on adult survival in Canada (Wellicome et al. In Press; Appendix 5). Specifically, precipitation on the wintering grounds and storms during migration both have negative effects on owl apparent survival in Canada (Wellicome et al. In Press; Appendix 5). The Burrowing Owl population in Canada also receives many first-year breeders from other parts of their range (Macias-Duarte 2011). If there are indeed rangewide increases in the frequency and intensity of extreme rainfall events this could reduce the number of first-year breeders into Canada. Both of these observations suggest that the population of breeding Burrowing Owls in Canada may be heavily influenced by climate factors outside of Canada and cannot be explicitly managed by actions on their breeding grounds. Further research using a combination of satellite telemetry, intensive monitoring along the Burrowing Owl migration route, and on their wintering grounds is needed to identify potential population bottlenecks. Further research also needs to identify whether migratory decisions (e.g., Ogonowski and Conway 2009) of Burrowing Owls may change as a result of human land use pressures and/or climate (Macias-Duarte 2011).

5.2 Effects of Climate Change on Burrowing Owl prey in Canada

The only Burrowing Owl population increase that has been observed in Alberta or Saskatchewan was the year after a meadow vole irruption in prairie Canada (Poulin et al. 2001). Burrowing owl reproductive output was abnormally high that year and subsequent recruitment the following year was also high (Poulin et al. 2001). It is clear that further research is needed to study how the interaction between climate change and landuse currently affects small mammal abundance and irruptions in prairie Canada (e.g., Heisler et al. 2014). For example, irruptions of one of the most important prey items for Burrowing Owls, meadow voles, is dependent upon winters with deep snow cover (Heisler et al. 2014). Current climate change predictions indicate that snow cover will likely decrease due to warmer winters (Lemmen and Warren 2004) which would in turn reduce the number of vole irruptions and would have a negative influence on Burrowing Owl reproduction. It is also uncertain how burrow engineers will respond to climate change. Understanding how burrow engineers and Burrowing Owl prey will respond to climate change are key factors in determining the effectiveness of our suggested adaptation strategies.

5.3 Effects of Drought on the Breeding Grounds

Drought conditions are expected to increase on the Canadian Prairies (Thorpe 2011). Studies in other parts of the Burrowing Owl range have showed reduced reproductive output of Burrowing Owls and reductions in prey availability under drought conditions (Gleason and Johnson 1985, Desmond and Savidge 1996). The Alberta Recovery Plan also indicates that drought coupled with overgrazing may have reduced foraging habitats of Burrowing Owls in the past (Alberta Environment and Sustainable Resource Development 2012). However, there is currently not enough information to determine how prolonged droughts might affect Burrowing Owls in Canada; but adaptively managing grazing by domestic livestock to benefit Burrowing Owls at the same time as maintaining high beef production would seem to be necessary in response to climate change (see section 4.3.1).

5.4 Potential responses of humans to climate change

In an effort to respond to climate change, human activities may inadvertently affect Burrowing Owls. For example, afforestation on marginal cropland (Van Kooten et al. 2002) as a means of carbon sequestration would effectively remove potential Burrowing Owl habitat, as Burrowing Owls avoid landscapes with a high proportion of trees (Thiele et al. 2013). Increases in the use of alternative energy sources could also negatively affect Burrowing Owls. Conversion of grassland to production of biofuels could remove significant tracts of Burrowing Owl habitat (Fargione et al. 2009). Increases in the number and geographic extent of wind energy facilities (i.e., turbines) may also be detrimental for Burrowing Owls. For example, Smallwood et al. (2007) found significant mortality of Burrowing Owls during migration around a wind energy facility in California.

5.5 Other limiting factors

It is unclear which non-climate factors might be influencing Burrowing Owls both on and off their Canadian breeding grounds. Although often cited as potential factors influencing population decline of Burrowing Owls in Canada, habitat loss does not necessarily appear to be limiting for Burrowing Owls in Canada (Environment Canada 2012) and there is little evidence that industrial development negatively influences

Burrowing Owls (Scobie et al. 2013). However, determining how landuse change and climate change might interact to influence Burrowing Owls appears to be an important future research objective.

6 Conclusions

As mentioned in other reports produced by our working group, Alberta's current Species-At-Risk appear to be most vulnerable to climate change (Shank and Nixon 2013). We have presented several adaptation options in this report for management of Burrowing Owls in the face of a changing climate, ranging from resilience and resistance options to more drastic response and triage options. Each is presented in Table 1 along with a comparative analysis of costs and likelihood of success. Many programs for habitat management in prairie Alberta, such as the MultiSAR and Operation Grassland Community programs and the recent Draft South Saskatchewan Regional Plan, already incorporate some aspects of the resilience and resistance options we present, namely habitat management. However, these strategies are currently limited to a relatively small area within the current range of Burrowing Owls in Canada and do not explicitly account for climate-induced changes on prairie flora and fauna. The federal Recovery Strategy indicates that Action Plans will be completed for this species in each jurisdiction (i.e., province) by December 2014. Because this Alberta-specific Action Plan is likely in the early planning stages, it may present a unique opportunity to incorporate some of these climate change adaptation strategies for Burrowing Owls. However, it is critical to note that responsibility for preservation of the species in Canada does not lie solely with

Alberta, rather interprovincial, federal, and international actions need to be developed to effectively manage this species in a changing climate.

Table 1 Climate change adaptation options for Burrowing Owls in Alberta. Presented are a listing of specific strategies in response to (1) changing average conditions and resulting distributional change of climate envelopes and vegetation communities, and (2) increases in the frequency and intensity of extreme weather events.

Strategy	Economic cost	Time-scale over which human-intervention might be needed	Scale of effect	Likelihood of positive outcome	Uncertainty of outcome
Distributional change					
Natural expansion	None	None	Large	Low	Medium
Reintroductions (i.e., within indigenous range)	High	Years - Decades	Small-medium	High	Medium
Assisted colonization (i.e., outside indigenous range)	High	Years - Decades	Small-medium	Medium	High
Adaptation options in response to changes in extreme rainfall					
Habitat management promoting abundant and accessible prey and suitable nesting burrows	High	Years	Large	High	Low
Artificial nest boxes to prevent flooding	Medium	Years - Decades	Medium	High	Low
Supplemental feeding to withstand inclement weather	Low	Years - Decades	Small-Medium	High [a]	Low

[a] – indicates the likelihood of a positive outcome in the short-term. That is, allowing owls to withstand inclement weather and maximize reproductive output. Long-term outcomes of supplemental feeding are uncertain.

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Appendix 1

Costs of reintroduction or assisted colonization of Burrowing Owls in Alberta. Costs arising before reintroductions or assisted colonization occur (e.g., site selection, predator and prey surveys, permit applications, landowner outreach and consultations) are not included. Cost estimates were provided courtesy Alexandra Froese (Manitoba Burrowing Owl Recovery Program, Program Manager; personal communication).

I. **Captive-breeding facility**

Is it possible that this cost could be shared with other organizations (e.g., Calgary Zoo). A new captive breeding facility in British Columbia was recently constructed in 2011 and the cost of the facility was estimated at approximately **$150,000**. Costs were, however, substantially reduced to less than $30,000 as a result of donations and fundraising. However, the facility is still a major expense if captive-reared birds are to be used in reintroductions. Other possibilities include the use of wild-caught birds, which would not require such a facility.

II. **Artificial nest box construction**

Item	Cost per ANB	Number of ANBs	Total
4in diameter weeping tile (burrow tunnels)	$4.96 per tunnel ($0.62/foot)	1	$4.96
Buckets	$3.97 x 2 per ANB	1	$8.00
Chicken wire	$0.15/ft^2 x 1.3 ft^2 per ANB	1	$0.20
Screws	8 screws per ANB	1	$0.40
Lumber	$1.38/ft^2/side x 5 sides per ANB	1	$6.93

Shovels (x 6)	-		$210.00
ANB construction time	3/4 hr per ANB @ $10/hr	1	$7.47
Installation time	2 hrs x 2 people	1	$40.00
		TOTAL	**$277.96**

III. Soft release pens

Item	# of units	Total
Lumber - 2x4's	5 per panel x 4 walls	$100.00
Fish netting/bird netting	1/4 inch holes	$200.00
Ladder		$60.00
Chicken wire	4 ft	$25.00
Snow fencing for roof	2 rolls for 6 pens	$80.00
Zip ties		$5.00
Bolts/washers/wingnuts		$30.00
Rope and bent rebar for anchors	4 anchors for each pen	$150.00
Sledgehammer		$45.00
Plywood for doorway	1 sheet for 2 doors	$50.00
Fence posts for roosting	1 post per pen	$8.00
Electric fencing posts	10 per pen	$7.00
Electric fence	1 roll - 100 ft	$40.00
Energizer (solar)	1 unit	$400.00
Post and wire for ground	1 per energizer	$10.00

TOTAL	$1,210.00

IV. Miscellaneous

Item	# of units	Cost
Mice	3 mice per day until release	$0.80 per mouse
Burrow camera (in burrows)	all accessories incl. battery	$4,400.00
Reconyx wildlife cameras (outside burrow)	1	$600.00
Rechargeable batteries for Reconxyx	6 per camera	$25.00
Binoculars		$300.00
Spotting scope	1-2 scopes for 3-5 staff	$600.00
	TOTAL	$5925.00^{+}

V. Personnel

Item	# of units	Cost
3 field assistants/project manager (PM)	1 PM @ $3500/month x 4 months + 3 field assistants @ $2000 per month x 3 months	$32,000.00
Truck rental	1 x 4 months	$8,000.00
Fuel	$900/month (assumes 5000 km per month @ 15L/100km fuel efficiency)	$3600.00
Accommodations for staff	4 months	$5,000.00
Landowner education	5 hours weekly x 2-4 staff	will vary
Pamphlets	1000	$250.00
Guidebooks	1000	$1,200.00

TOTAL	$50,050.00⁺

Appendix 2

Costs (CDN) of supplemental feeding Burrowing Owls for one year. Costs beyond the actual field aspect of supplemental feeding are not included (e.g., surveys to locate nests, landowner contacts, permit applications, housing in the field, use of ATVs if conditions warrant, etc.). Ideally local volunteers could be solicited to conduct the supplemental feeding and this would substantially reduce costs. Thus, the following costs would be incurred if this was solely a program run by one organization.

Item	Cost per item		Number of nests	Total
Mice	$0.80/mouse	6 weeks x 2 times per week	75	$720
Plastic bags to hold mice	$200	-	-	$200
Truck rental	$2000/month	2 months x 3 trucks	-	$12,000
Fuel	$900/month/truck (assumes 5000 km per month @ 15L/100km fuel efficiency)	3 trucks x 2 months	-	$5,400
Salary for field technicians	$3500/month for crew leader; $2000/month for 3 assistants	1 crew leader x 2 months; 3 assistants x 2 months	-	$19,000
			TOTAL	**$37,320**

Appendix 3

Costs (CDN) of artificial nest box (ANB) installation for Burrowing Owls in Alberta. Costs are based on the Canadian design (Johnson et al. 2013; Figure 5). Costs do not include activities leading up to ANB construction (e.g., site selection, nest monitoring [if replacing active burrows], landowner contacts, etc). The initial installation would be a one-time cost; however, yearly maintenance (also presented) of these nest boxes to ensure that they remain useable by Burrowing Owls and in inhabitable condition is also calculated. Costs in terms of salaries could be substantially reduced if volunteers were included.

I. Costs of artificial nest box construction and installation

Item	Cost per ANB	Number of ANBs	Total
4in diameter weeping tile (burrow tunnels)	$4.96 per tunnel ($0.62/foot)	75	$372.00
Buckets	$3.97 x 2 per ANB	75	$600.00
Chicken wire	$\$0.15/ft^2$ x $1.3\ ft^2$ per ANB	75	$15.00
Screws	8 screws per ANB	75	$30.00

Lumber	$1.38/ft^2/side x 5 sides per ANB	75	$520.00
Shovels (x 6)	-	75	$210.00
ANB construction time	3/4 hr per ANB @ $10/hr	75	$560.00
Installation time	2 hrs x 2 people	75	$3,000.00
		TOTAL	**$5307.00**

II. Costs of ANB upkeep for 1 year.

Item	**Cost**		**Total**
Personnel	$2000/month x 1 month x 4		$8,000.00
Truck rental	$2000/month x 1 month x 2 trucks		$4,000.00
Fuel	$900/month/truck		$1,800.00
Miscellaneous repair materials	$500		$500.00
		TOTAL	**$14,300**

Appendix 4

Abstract of major effects of extreme weather on Burrowing Owl reproductive success in Canada.

1. Climate-change scenarios predict that the frequency and intensity of extreme weather will increase. Many studies have examined how avian reproductive output could be influenced by future changes in average conditions, yet few have determined empirically how reproductive output is affected by extreme weather. Human landuse may buffer or exacerbate susceptibility of birds to extreme weather.
2. Using an 8-year study in Canada (2003-2010) we examined how burrowing owl *Athene cunicularia* nest survival varied in relation to daily temperature and precipitation, vegetation type, and soil texture. In addition, we compared burrow reoccupancy rates the year following nest flooding, nest depredation, and successful nesting. Using a 3-year (1992, 1993, and 1996) supplemental feeding experiment and individual marking, we examined whether food limitation is one of the mechanisms underlying owlet mortality during inclement weather.
3. Nest survival decreased during 1-d extreme precipitation events, but there was no interactive effect between precipitation and landuse. Flooded nests had a significantly lower reoccupancy rate compared to nests that were successful, but the same rate as depredated nests. Almost all owlets receiving supplemental feeding

survived bouts of inclement weather; whereas, the youngest owlets in unfed broods experienced substantially reduced daily survival rates under all levels of precipitation. ***Synthesis and applications***: Increases in the intensity and frequency of heavy-precipitation events in North America during the breeding season could have adverse consequences on population growth of burrowing owls. Our results suggest that food limitation is one of the main mechanisms causing reduced reproductive output. Supplemental feeding could be considered as a short-term, stop-gap measure for management of burrowing owls, but more importantly, habitat management at the scale of the home range ensuring an abundant and available food source during the breeding season is critical for owls to withstand predicted increases in heavy rainfall events. In areas where owls use artificial nest boxes, upkeep and maintenance of boxes could be useful to prevent further degradation of the pool of available nest burrows and promote reoccupancy even after rain events may damage a burrow.

Appendix 5

Apparent survival of adult Burrowing Owls in Canada is influenced by weather during migration and on their wintering grounds.

Understanding factors influencing survival of endangered, migratory species is critical for making informed management decisions, yet this understanding relies on long-term recapture datasets for species that are, by definition, rare. Using three geographically widespread (Saskatchewan, Alberta, and Manitoba, Canada) and long-term (6 -15 years) mark-recapture datasets, we quantified spatial and temporal variation in apparent annual survival and recapture probabilities of Burrowing Owl (*Athene cunicularia*), an endangered species in Canada. We then examine how large-scale weather patterns during migration (storms) and on the wintering and breeding grounds (precipitation), in addition to prey irruptions on the breeding grounds, influence apparent survival of Burrowing Owls. Female Burrowing Owls had lower apparent survival compared to males in all three study areas. Storms during fall migration and above-average precipitation on the wintering grounds were associated with reduced apparent survival of owls in the longest-running study area, Saskatchewan; in Alberta and Manitoba, there were few correlations between apparent survival of owls and weather or prey irruptions. Increases in stochastic events such as storms during migration or precipitation on the wintering grounds could have adverse consequences on the already small Burrowing Owl population in Canada. Local management actions that focus solely on improving adult apparent survival within Canada are likely insufficient for mitigating susceptibility of adults to inclement weather, or other factors, outside the breeding season, justifying the need for management of this species across multiple jurisdictions within North America.

Citation: Wellicome, T.I., R.J. Fisher, R.G. Poulin, L.D. Todd, E.M. Bayne, D.T.T. Flockhart, J.K. Schmutz, K De Smet, and P.C. James. In Press. Apparent survival of adult Burrowing Owls in Canada is influenced by weather during migration and on their wintering grounds. Condor: Ornithological Applications.