Restoration plan for Western burrowing owl (*Athene cunicularia hypugaea*), BC

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Executive Summary

Western burrowing owls (*Athene cunicularia hypugaea*; BUOW) are small, long-legged predatory raptors that are found in the Southern Interior of BC near Kamloops and Merritt. BUOW are Red-listed and Endangered under the BC Wildlife Act and listed as Endangered by the Species at Risk Act and the Committee on the Status of Endangered Wildlife in Canada. In Canada, BUOW breeding range has decreased to a third of what it was in the 1970s, and density has declined by 90% since 1990. Generally, the Canadian population is declining at >10% annually.

Population limits include low productivity, low post-fledging survival, low annual survival of juveniles and adults, and high annual dispersal (i.e. a net emigration to the US and Mexico). Key stressors and limiting factors include reduction in prey species, increased climate change and severe weather events, vehicle collisions, incompatible renewable energy and agricultural practices, increased predator abundance, and overall loss, degradation, and fragmentation of natural grasslands.

The focus of this plan is to identify restoration treatments that will enhance BUOW foraging conditions in the southern interior of BC. Prey abundance is known to limit reproduction, and home ranges have been shown to decrease during periods of superabundance of small mammals. High quality insect food sources adjacent to burrows for daytime foraging and nearby small mammal food sources for nocturnal foraging appear to be critical factors. Thus, this plan focuses on treatments that will enhance BUOW natural food sources near artificial burrows that correspond with natural diurnal and nocturnal foraging habits.

Recommended treatments are divided into two zones based on key prey taxa. Grasshopper zone (i.e. 0 to 50 m from burrow) treatments include creating sparse and patchy native grass and forb conditions, and applying biosolid amendments to support desired plant species, to provide horizontal visibility for BUOW, and to increase grasshopper abundance. Vole zone (i.e. 50 to 150 m from burrow) treatments include establishing ungrazed young riparian forest to promote small mammal availability far enough from nest sites to discourage depredation but close enough to be bioenergetically available. Alternatively, burrows can be established 50 to 150 m from existing ungrazed young riparian forests.

BUOW and prey species monitoring is recommended, before and after treatments, for five consecutive years. To reduce impacts on BUOW, we recommend applying an equal number of treatments be applied in areas without burrows and for prey species monitoring to occur on those treatments.

Finally, we recommend additional research on prey species requirements, vegetation species composition and structure, migration pathways, and monitoring methods to better inform restoration efforts. We also recommend working with local, national, and international groups to create best management practices and knowledge share across the entire BUOW range.

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1 Physical Description

The Western burrowing owl (*Athene cunicularia hypugaea*; hereafter referred to as BUOW) is a small, long-legged predatory raptor species (SAR Public Registry 2018). The BUOW is a brownish to white mottled owl with bright large yellow eyes, a round head lacking ear tufts, a short tail, large wings averaging 51-61 cm across, and is approximately 23 to 28 cm tall (MWLAP 2004, Parks Canada Agency 2012). Western BUOW is one of two subspecies in North America, and 1 of 18 recognized subspecies across both the American continents. The BUOW has become a flagship species for the conservation of prairie and grassland habitat.

2 Species Requirements

In BC, BUOW are found only in the Southern Interior near Kamloops and Merritt (Mitchell et al. 2011), and are associated with communities dominated by big sagebrush (*Artemisia tridentata*), antelope-brush (*Purshia tridentata*), and bunchgrass (*Agropyron* and *Festuca* spp.). BUOW are found from 335 to 1250 m in elevation (MWLAP 2004) in the Bunchgrass biogeoclimatic zone, especially the Nicola very dry warm variant (i.e. BGxw1 subzone and variant) and the Thompson very dry hot variant (i.e. BGxh2 subzone and variant; Mitchell et al. 2011).

In Canada, BUOW are found in open prairie habitats, sparsely vegetated grasslands, agricultural fields, and scrubland with suitable burrow sites (SAR Public Registry 2018, COSEWIC 2017, SAR Public Registry 2011). Resident BUOW in the Pampas of Argentina select nest sites in vegetated sand dunes, periurban areas, and agroecosystems, and are considered habitat generalists (Martinez et al. 2017). BUOW are secondary nesters and prefer burrows created by fossorial mammals such as ground squirrel (*Spermophilus* spp.), black-tailed prairie dog (*Cynomys ludovicianus*), yellow-bellied marmot (*Marmota flaviventris*), American badger (*Taxidea taxus*), red fox (*Vulpes vulpes*), and coyote (*Canis latrans*; SAR Public Registry 2018, COSEWIC 2017, MWLAP 2004). BUOW often excavate these burrows to create larger areas for egg laying (MWLAP 2004). BUOW then further modify burrows by adding cow manure before eggs are laid, to disguise their scent from potential predators. Once prepared, male BUOW will advertise to potential mates in the area (MWLAP 2004). Burrows, 'eavesdropping' on the calls of other species, and mimicking the hissing of rattlesnakes help protect BUOW from predators (Cavalli et al. 2018a, Audubon 2015).

In 2004, burrow availability was considered a limiting factor for this species, as burrows are fiercely defended against conspecifics (MWLAP 2004). Critical habitat identified in the final Recovery Strategy for the species remains synonymous with the limits of black-tailed prairie dog colonies in Canada in 2007 (Parks Canada Agency 2012). However, since both artificial and natural burrows appear to occur with abundance in these areas and the population trend is still in decline, it is likely that another factor is limiting (D. Ransome BCIT pers. comm.). Nest failures and low juvenile survival are thought to be the main cause of decline (SAR Public Registry 2018). Mean clutch size for wild populations is 3.6 to 8.3, compared to 5.6 for released BC populations. Eggs undergo a 21-30 day incubation. Juveniles emerge 20-25 days later, shortly after which fledglings begin to move between burrows. Mean brood size for wild populations is 2.1 to 6.3, compared to 4.1 for released BC populations (MWLAP 2004). In Oregon, nest failure was most likely caused by desertion due to proximity of other nesting pairs, followed by depredation of nests by American badger (Green and Anthony 1989). Nest locations were found to be usually in areas with shorter and less dense vegetation relative to the surrounding landscape. Shorter grasses aid in predator detection or perhaps increase availability of invertebrate prey (MWLAP 2004, Green and Anthony 1989). BUOW selected nest sites with lower shrub volumes than surrounding areas which may indicate a trade-off between high number of potential perches and minimum horizontal visibility (Green and Anthony 1989). Owls significantly preferred grass-forb areas (Haug and Oliphant 1990), and forbs, grasses and bare ground are important for foraging in human-altered landscapes (Chipman et al. 2008).

Prey abundance is known to limit reproduction (Mitchell et al. 2011), and home ranges have been shown to decrease during periods of superabundance of small mammals (from 0.14 - 4.81 km^2 to 0.08 - 0.49 km^2; Sissons et al. 1998).

BUOW diet consists of insects and small mammals, and varies by season (i.e. invertebrates during spring and early summer, shifting to small mammals later in the year; MWLAP 2004). In Oregon, vertebrate consumption has been shown to shift from 25 to 50% vertebrates in early summer to almost 0% in late summer (Green and Anthony 1989). In Brazil, BUOW diet was found to be numerically 66 to 97% invertebrates (i.e. mostly termites, grasshoppers, and beetles), with seasonal dependence on termites during the dry season and on beetles during the wet season (Motta-Junior and Bueno 2004). However, by biomass, 46 to 92% of BUOW diet was consistently composed of small rodents (Motta-Junior and Bueno 2004). This is supported by Herse (2019) who studied an extralimital BUOW pair in Kansas and found that arthropods represented 90.8% of prey items, and 39.2% of biomass (Herse 2019). Owls consumed more insects than vertebrates during all breeding stages, but biomass of vertebrates increased in later breeding stages (e.g. 78.7% during brood-rearing; Herse 2019).

Foraging habits also vary by time of day. Unlike most owls, the BUOW is mainly a diurnal hunter (MWLAP 2004). During the day, BUOW generally forage near nesting sites in sparse vegetation for insects and at night, forage further away for small mammals in dense vegetation (SAR Public Registry 2018, MWLAP 2004). In Saskatchewan, daytime foraging occurred within 50 m of nest or satellite burrows (Haug and Oliphant 1990). In Kansas, owls consumed more grasshoppers than other prey (>50% items), brought most of their prey to the burrow during the day (>90% items), only brought rodents to the burrow at night, and only brought birds and reptiles during the day. Aerial insect predation is more common at urban sites than rural sites (Chipman et al. 2008).

In BC, night foraging occurred mostly along riparian areas in ephemeral ponds and moisture seepage sites, and to a lesser extent along the sides of gravel roads (MWLAP 2004). In Saskatchewan, nocturnal foraging occurs in road and rail rights-of-way, uncultivated fields, and ungrazed fields with taller vegetation (i.e. vegetation ≥30 cm tall; Haug and Oliphant 1990). Peak hunting activity (i.e. flights >50 m) occurred between 2030 and 0630, and involved mostly males hovering and small mammal foraging (Haug and Oliphant 1990). 95% of owls stayed within 600m of burrows to forage (Haug and Oliphant 1990).

High quality insect food sources adjacent to burrows for daytime foraging and nearby small mammal food sources for nocturnal foraging appear to be critical factors (MWLAP 2004).

3 Conservation Status

From 1979 to 2002, the BUOW was designated as a threatened species, then in 2003, BUOW was re-designated as a Schedule 1 Endangered species under the Species at Risk Act (SARA; SAR Public Registry 2018). The BUOW is also listed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2002, COSEWIC 1978).

Provincially, BUOW is red listed in BC (SAR Public Registry 2018). Under the BC Wildlife Act, BUOW is designated as Endangered and is one of the few species listed in Section 34b for which nests are protected year-round, regardless of active or inactive status (MWLAP 2004). Both a national recovery team, and BC recovery team have been established to protect BUOW (MWLAP 2004)

4 Abundance and Distribution

BUOW are found in southern Canada, most parts of western and central United States, Mexico, and as far south as Panama (Figure 1, SAR Public Registry 2018). BUOW abundance has declined throughout its breeding range, especially in Canada, Washington, Oregon, and Eastern California. However, populations in Colorado, Texas, and Mexico are thought to be stable (MWLAP 2004). There has been a 90% decrease of BUOW between 1990-2000 and declines of 75% between 2000-2015 (MWLAP 2004). BUOW migration paths across North America are relatively unknown. Owls banded in BC have been located in Washington, Oregon, and California, suggesting their migration routes are through the Great Basin and into the southern coastal plains of California (Leupin et al. 2000, MWLAP 2004). For BUOW in Mexico, the population trends are largely unknown.

In Canada, BUOW are found in British Columbia, Alberta, Saskatchewan, and Manitoba (MWLAP 2004). Migration to Canadian breeding areas occurs between April and May (SAR Public Registry 2018). In 2018, Canadian breeding range was less than half of its range in the 1970s and just a third of its range in the 1900s (SAR Public Registry 2018). Additionally, BUOW density decreased by 90% from 1990 to 2000 (SAR Public Registry 2018). Generally, the Canadian population is declining at >10% annually (Holroyd 2000, MWLAP 2004). The most recent estimate of Canadian population size was a minimum of 795 mature individuals: 498 in Saskatchewan, 288 in Alberta, and 9 in British Columbia (COSEWIC 2004).

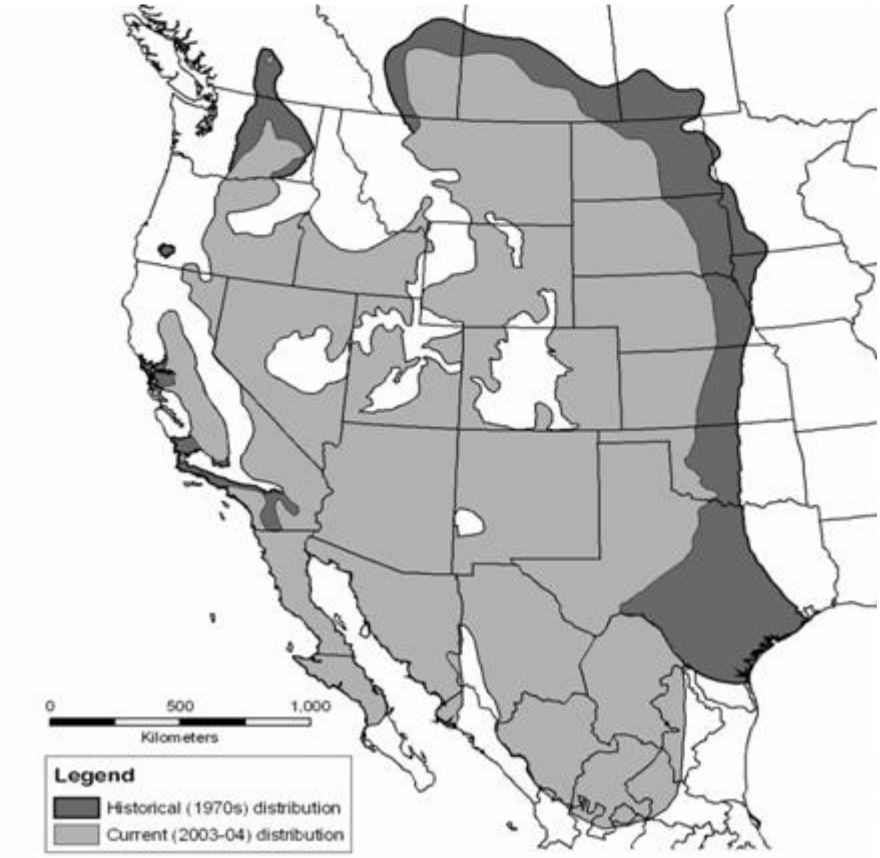

Figure 1: Reduction in Western burrowing owl distribution between the 1970s and 2004 in North America (Environment Canada 2012)

5 Stressors and Limiting Factors

Factors that limit the burrowing owl's population in Canada are low productivity, low post-fledging survival, low annual survival of juveniles and adults, and high annual dispersal (i.e. a net emigration to the US and Mexico; SAR Public Registry 2018). It is unclear why the annual return of breeding adults to BC remains low (<2% return rate on reintroduced individuals; Mitchell et al. 2011).

Historically, population declines were caused by conversion of grassland to cropland, as well as fragmentation and degradation of remaining grassland habitat (SAR Public Registry 2018). In BC, grasslands only represent <1.5% of land area and much of our native grasslands have been converted to agricultural crops, orchards, and urban areas. Grasslands that remain are highly fragmented, and contain reduced vegetation, prey and fossorial mammal diversity (MWLAP 2004). Loss of fossorial mammals has reduced natural burrow availability (Proulx 2014)

Other main threats include reduction in prey, climate change and severe weather, vehicle collisions, renewable energy projects, incompatible grazing or farming practices, and predation (SAR Public Registry 2018, MWLAP 2004). Increased precipitation in the Canadian breeding range has lowered productivity of owls by 12% (Fisher et al. 2015). In BC, vehicular collisions do not appear to be significant, of 220 owls released since 1992, only one death due to vehicle collision (MWLAP 2004). Approximately 440 BUOW per year are killed by wind turbines in Altamont Pass Wind Resource Area, California (Smallwood et al. 2007). BUOW are increasingly common in human-altered landscapes (Griffin et al. 2017). In urban settings, BUOW in Argentina have demonstrated habituation responses towards human stimuli (Cavalli et al. 2018b) and a genetic founder effect was discovered in colonized South American cities (Mueller et al. 2018). In developed areas in New Mexico, BUOW had the highest mortality in greenspaces compared to urban and agricultural areas (Griffin et al. 2017). In Texas, high rates of human disturbance and areas of refugia for generalist predators subject juveniles to increased predation (Chipman et al. 2008). Urban sites have increased disturbance, rural sites have increased predator abundance (Chipman et al. 2008).

Prey abundance is reduced by rodenticides and pesticides (COSEWIC 2017, Mitchell et al. 2011) and BUOW offspring production is decreased by 54 to 83% when pesticides are applied around burrows (James and Fox 1987). BUOW may also be exposed to lead poisoning if they live in areas where small mammals are shot (McTee et al. 2019). Vole availability has a greater impact on BUOW population growth than reproductive impairment from insecticide if vole populations peak and crash frequently, but this difference disappears when crash year frequency decreases (Gervais et al. 2006a).

Predator abundance has increased since historical times and is believed to be associated with agricultural development. Main predators are coyotes, red-tailed hawks (*Buteo jamaicensis*) and other raptors that have benefited from the creation of perching structures in grassland systems (MWLAP 2004). In BC, predation on reintroduced adults and young is high (e.g. 71% adult mortality within first month of release).

6 Recovery Progress BC

The main BUOW recovery strategy has been to establish captive breeding programs, which has been met with some success across BC. As of 2004, release of BUOW is concentrated around the Lac du Bois Grasslands, Knutsford, Hamilton Commonage, and Quilchena areas (MWLAP 2004). Most BUOW habitat exists on private lands, with only a small proportion under Crown ownership (MWLAP 2004). Of the captive bred owls, more than 250 one-year-old owls mated and produced young in subsequent years (e.g. in 2002, four from previous year, and three older adults returned to the same area and 'some' of the owls produced young). In BC, release of captive-bred owls began in the 1980s in Cache Creek, Merritt, Kamloops, and Oliver (SAR Public Registry 2018).

As of 2004, there have been no effective management measures that have increased or stabilized the population of BUOW in BC (MWLAP 2004). To increase survival, artificial burrows and supplemental food are often provided (SAR Public Registry 2018). A substantial focus has been put on outreach programs with private landowners, since most BUOW are located on private lands (SAR Public Registry 2018). Other methods of recovery focus on school, public education, and volunteer programming.

Future monitoring of BUOW in BC must be done to better understand limiting factors in both breeding and overwintering ranges (SAR Public Registry 2018), especially an understanding of ideal habitat requirements (MWLAP 2004). It will be important to protect large areas of BUOW habitat as current legislation only protects relatively small and fragmented areas (MWLAP 2004).

7 Desired Future State

The long-term recovery goal for BUOW is to reverse the population decline in Canada and maintain a self-perpetuating, well-distributed population of at least 3000 breeding pairs within the four western provinces (SAR Public Registry 2018). The most recent estimate of population size in 2004 was a minimum of 795 mature individuals: 498 in Saskatchewan, 288 in Alberta, and 9 in British Columbia (COSEWIC 2004).

Sites with high insect and small mammal prey abundance, high levels of horizontal heterogeneity, and low density of vegetation should be protected and restored to improve reproductive success (Green and Anthony 1989).

Migration corridors, as well as direct and indirect sources of mortality during migration, should be identified and studied to determine management strategies at an international scale.

8 Restoration Goals and Objectives

Goal: At BC reintroduction sites, apply treatments that will enhance BUOW natural food sources near artificial burrows that correspond with natural diurnal and nocturnal foraging habits.

> **Objective 1**: From 0 to 50 m from burrow, create sparse and patchy native grass and forb conditions (i.e. >40% bare ground, e.g. big sagebrush (*Artemisia tridentata*), antelope-brush (*Purshia tridentata*), and bunchgrass (*e.g. Festuca* spp.)) to enhance grasshopper abundance and horizontal visibility.
>
> **Objective 2**: From 0 to 50 m from burrow, apply biosolid amendments in and around vegetation patches to enhance grasshopper abundance and support the growth of desired plant species.
>
> **Objective 3**: From 50 to 150 m from burrow, establish ungrazed young riparian forest to promote small mammal availability far enough from nest sites to discourage depredation but close enough to be bioenergetically available. Alternatively, establish burrows 50 to 150 m from existing ungrazed young riparian forests.

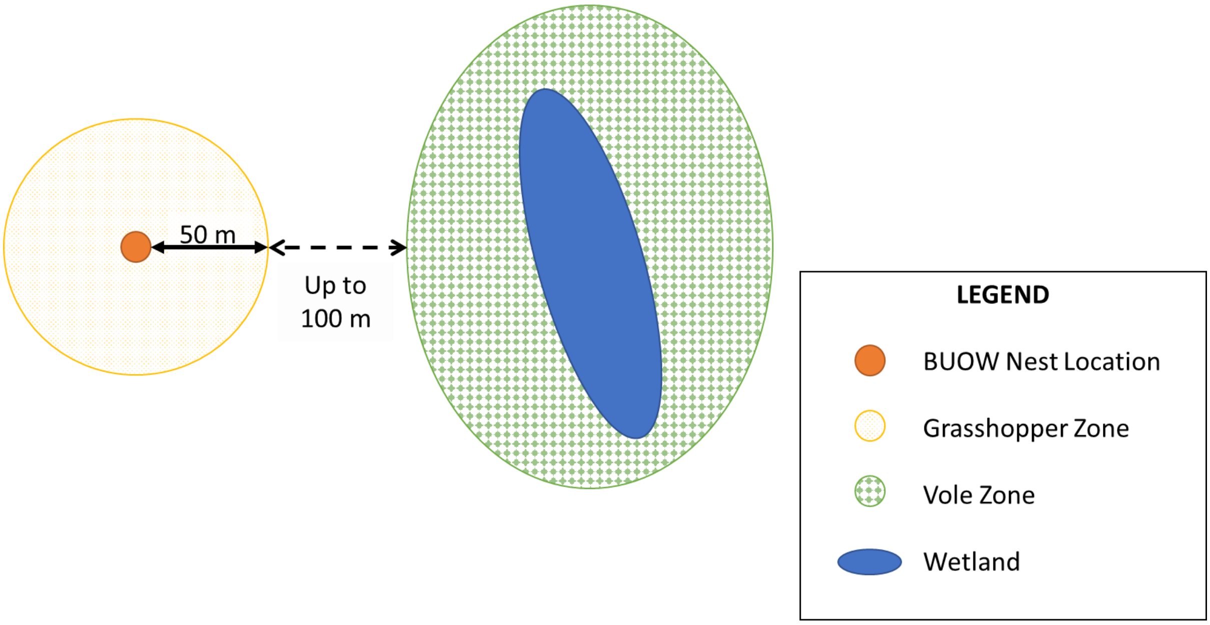

Figure 2: Schematic of Grasshopper and Vole restoration zones relative to burrowing owl (BUOW) nest locations

9 Treatments

We suggest applying additional grasshopper and vole abundance treatments to 50% of artificial burrows (hereafter referred to as treatment burrows) and maintaining traditional treatments on the remaining 50% of artificial burrows (hereafter referred to as control burrows).

9.1 Grasshopper Zone

Grasshoppers are often the dominant native herbivore in grassland ecosystems worldwide (Branson 2010), and the most important invertebrate herbivore in North American grasslands (Griesdale 2005).

Orthopteran species richness is strongly correlated with percent bare soil, and many grasshopper and cricket species oviposit on bare or exposed soils (Gaudreault et al. 2019). Grasshoppers were found to be most abundant when bare soil >40% (Anderson 1964) Therefore, prior to BUOW arrival (i.e. before April), we recommend mowing and heavy tilling patches of ground (i.e. totalling >50% of the area) within 50 m from treatment burrows to promote grasshopper abundance.

Most grasshopper species are generalists, and grasshopper abundance does not appear to be correlated with plant cover or plant species richness (Branson 2010). Therefore, in areas that do not receive bare-ground treatments, we recommend retaining or planting native forbs and shrubs to reduce invasive species establishment and provide BUOW horizontal heterogeneity requirements (Green and Anthony 1989, RDOS 2020). Forbs and shrubs should be planted in the fall or early winter (Benson et al. 2011). See Table 1 for recommended species and associated costs.

Table 1: Recommended plant species for Grasshopper zone treatments for Western burrowing owl restoration plan in BC.

Common Name	Scientific Name	Cost per unit
Big Basin Sage	*Artemisia tridentata*	$5.50 / 4-inch pot
Antelope Brush	*Purshia tridentata*	$5.99 / 4-inch pot
Fescues	*Festuca* spp. *Festuca campestris* *Festuca glauca* *Festuca idahoensis*	 $10.99 / 1-gal pot $10.99 / 1-gal pot $1.65 / plug

**Cost derived from Sagebrush Nursery in Oliver, BC during March 2022 (Sagebrush Nursery 2022)*

Application of biosolids (i.e. pathogen-treated wastewater remains) has been shown to increase grasshopper densities in northern grasslands in BC (Gaudreault et al. 2019). We suggest applying biosolids in and around the patches of vegetation to promote growth of desired plants and increase grasshopper density. In northern grasslands, short-eared owls (*Asio flammeus*) strongly preferred to target voles in pastures treated with biosolids (Ormrod et al. 2021). It is possible biosolid treatments may also support small mammal abundance.

9.2 Vole Zone

Vole species are considered keystone species due to their importance as prey species for a diversity of predators, their generalist foraging habits, and their burrowing activity (Sullivan et al. 2021). Avian predators of small mammals exhibit spatial and prey convergence responses. However, these responses are complex and based on individual response to prey abundance, vegetation structure and other predators (Ormrod et al. 2021). As BUOW experience high rates of avian predation and nest depredation, we recommend efforts to increase vole abundance and density be concentrated more than 50 m from treatment burrows to avoid attracting competitors and predators to nest sites. However, treatments should be within BUOW nocturnal foraging range to ensure prey is bioenergetically available (i.e. between 50 and 600 m from burrow; Haug and Oliphant 1990). Therefore, we recommend small mammal enhancement efforts be focused from 50 to 150 m from treatment burrows.

In southern BC, montane voles (*Microtus montanus*) are found in valley bottoms in native bunchgrass-sagebrush communities and perennial grasslands (Sullivan et al. 2021). Voles are likely more abundant in grasslands adjacent to wetland or riparian areas in the Okanagan than in other habitat types due to higher moisture and, therefore, healthier grassland conditions (D. Randsome BCIT pers. comm.). Riparian cottonwood forest ecosystems in the Okanagan support a high abundance of small mammals and insects, and due to loss associated with human impacts, are now endangered ecosystems in the Southern Interior (MELP 1997). In xeric environments, riparian resources such as food, cover, and water, are often unavailable or limiting. Small mammal richness, abundance, and evenness is higher in riparian areas across a variety of temporal and spatial scales (Hamilton et al. 2015). BUOW have been observed hunting for voles and other small mammals in areas with taller vegetation (i.e. vegetation ≥30 cm tall; Haug and Oliphant

1990). For the aforementioned reasons, we suggest establishing young riparian forests and the conditions to support them within 50 to 150 m from treatment burrows.

Most small mammal species were found within 500 m of streams, with montane voles mostly found within 200 m of streams (Hamilton et al. 2015). We recommend excavating wetlands or streams at or just beyond 150 m from treatment burrows. Alternatively, treatment burrows can be established at or just beyond 150 m from existing wetlands or streams.

We suggest retaining or planting native riparian vegetation from 50 to 150 m from treatment burrows to provide food and cover for voles. See Table 2 for species list and associated costs.

Table 2: Recommended plant species for Vole zone treatments included in Western burrowing owl restoration plan in BC.

Common Name	**Scientific Name**	**Cost per unit**
Black Cottonwood	*Populus trichocarpa*	$12.00 / 1-gal pot
Paper Birch	*Betula papyrifera*	$12.00 / 1-gal pot
Common Snowberry	*Symphoricarpos albus*	$12.00 / 1-gal pot $1.65 / plug
Red-Osier Dogwood	*Cornus stolonifera*	$12.00 / 1 gal pot

**Cost derived from Sagebrush Nursery in Oliver, BC during March 2022 (Sagebrush Nursery 2022)*

Meadow voles (*M. pennsylvanicus*) are more abundant in ungrazed fertilized young forest than in grazed fertilized young forest (Sullivan and Sullivan 2015). Therefore, we recommend livestock exclusion fencing or cattle ramps to control livestock access to wetlands and rivers and protect riparian vegetation (George and Murphy 2015).

10 Monitoring Plan

To evaluate if restoration treatments were successful in increasing prey abundance, we recommend establishing a before-and-after, control-intervention (BACI) monitoring plan. As described previously, we recommend applying grasshopper and vole treatments and traditional treatments to half (i.e. 50%) of the artificial burrow sites (i.e. treatment burrows), and only maintaining traditional treatments on the remaining artificial burrows (i.e. control burrows). Pre- and post-restoration monitoring efforts should be conducted on both treatment and control burrows.

An equal number of treatment sites should be made in areas where no artificial burrows present, this would allow for more extensive prey abundance surveys to happen without potentially negatively affecting BUOW. To determine the effectiveness of treatments on BUOW prey abundance, we suggest conducting grasshopper and small mammal surveys on both treatment and control sites, before and after treatments. Grasshopper abundance, richness and evenness can be assessed using hoop transects and timed net samples (Gaudreault et al. 2019). Vole abundance, richness, and evenness can be assessed using Sherman or Longworth traps along transects that are perpendicular to the water source

(Hamilton et al. 2015). Owl pellets can also be collected before and after treatments to help determine how prey abundance may be affecting BUOW movement and activity periods (Haug and Oliphant 1990).

On treatment and control sites that contain BUOW nests, we suggest five consecutive years of BUOW reproductive output, survival, and annual return research be completed. To evaluate demographics, individuals must be identifiable, ideally from a distance. Therefore, all re-introduced owls involved in this study should be colour and alphanumerically banded. To assess reproductive output, we recommend counting eggs laid, chicks hatched, and fledging numbers. If monitoring is being done with limited resources, an equal number of burrows can randomly be selected from both treatment sites and control sites. After release, burrows will be surveyed in 10-day intervals until clutches are complete, assuming one egg will be hatched every 1.5 days (Wellicome 2005). To minimize stress on juvenile birds, we recommend biweekly visual surveys of hatchlings and fledglings at burrow entrances. Once all owls have fledged, they can be captured and banded similar to the captive bred owls and a subset can be given radio tags. Radio tags should be used conservatively as BUOW have been shown to be negatively impacted by radiotransmitters, regardless of mounting method, age, site location, or years (Gervais et al. 2006b). Any juvenile survival surveys should take place between the post-fledging period (40 days after hatching) and permanent dispersal or migration in early September (Mitchell et al. 2011).

To evaluate annual return, we recommend surveyors complete biweekly visual transect surveys that ensure good area coverage during March to November annually when owls are returning to the southern interior of BC.

11 Maintenance

We recommend repeating bare ground or vegetation treatments if monitoring results show a more than 10% change in optimal conditions (e.g. if bare ground <30% in Grasshopper zones, or >10% loss of native riparian vegetation cover in Vole zones).

12 Recommendations/Discussion

This study, and additional research into prey species requirements, could provide key insights for grassland ecosystem restoration. Understanding prey species requirements will aid in the design of treatments that support arthropod and small mammal populations, and the populations of animals that depend on them. We recommend additional surveys on keystone and low-trophic species to inform restoration plans for predatory species.

While both grasshoppers and voles are key food sources for BUOW, there may be negative impacts associated with increasing their abundance in the southern interior of BC. These species are a benefit to BUOW but can be detrimental to agricultural activities. Grasshoppers sometimes demonstrate epidemic outbreaks and impact crop yields (Gaudreault et al. 2019). Voles can inflict serious damage on important fruit crops in the Okanagan Valley by feeding on bark, and roots during the winter (Sullivan and Sullivan 1988). We recommend outreach to local communities and farms to improve best practices and mitigate economic impacts.

Vegetation species composition and structure around burrow sites has been heavily altered in BC grassland systems (MELP 1997). BUOW has complex vegetation structure needs (e.g. high levels of habitat heterogeneity; Green and Anthony 1989), therefore research into the multiple variables that create ideal vegetation characteristics for BUOW habitat requirements is recommended. Once riparian forest ecosystems are established around burrows, reintroducing low intensity fires via prescribed burning treatments could prevent encroachment and support the ecological health of both diurnal and nocturnal foraging habitat (MWLAP 2004).

A key recommendation for BUOW restoration is to encourage international knowledge sharing and monitoring efforts to better understand why BUOW are not returning to breeding areas in southern BC. This could also help better understand mortality rates during winter migration, which could help explain the low return rates of the BUOW. We recommend establishing an international working group with members from National and Provincial recovery teams, and publishing reports that encompass the entire BUOW range.

While banding and radio tagging owls is important for understanding migration patterns, banded owls have been found less likely to return to released sites than non-banded owls (Gervais et al. 2006b). 69% of tagged juvenile owls died within the first 15 weeks, the cause of death was most commonly predation (Gervais et al. 2006b). Although tags weigh on average 3% of a juvenile's body weight (Mitchell et al. 2011), researchers believe that the mounting system (i.e. rather than the added weight) was to blame. Many owls were observed biting at the harnesses and preening, and the most frequent known cause of death was predation, possibly due to distraction. Harnessed owls were not as vigilant and perhaps not as attentive to young, as owls without harnesses; Gervais et al. 2006b). Further research into survey methods could yield higher return rates and lower juvenile mortality.

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