Connecting Habitats in the Prairies of Alberta: What Does This Mean and How Do We Manage for It?

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LIST OF ACRONYMNS

ABMI — Alberta Biodiversity Monitoring Institute

ACIMS — Alberta Conservation Information Management System

AEP — Alberta Environment and Parks

AESRD — Alberta Environment and Sustainable Resource Development

ANPC — Alberta Native Plant Council

CFIA — Canadian Food Inspection Agency

COSEWIC — Committee on the Status of Endangered Wildlife in Canada

EC — Environment Canada

GNLCC — Great Northern Landscape Conservation Cooperative

NABCI — North American Bird Conservation Initiative

NAWMP — North American Water Management Plan

PCAP — Prairie Conservation Action Plan

PHJV — Prairie Habitat Joint Venture

SAR — Species at Risk

USDA — United States Department of Agriculture

1. Introduction

Alberta's prairies are vibrant, diverse, and productive grassland ecosystems, forming the northern tip of the central grasslands of the North American Great Plains, which extend south into central Mexico. In Alberta, at the prairie's northern and western edges, the Grassland Natural Region mixes with woodlands to form the Parkland Natural Region. A high diversity of species inhabits the grassland ecosystems, including greater sage-grouse (*Centrocercus urophasianus urophasianus*), pronghorn (*Antilocapra Americana*), prairie rattlesnake (*Crotalis viridis*), and the Great Plains toad (*Bufo* [*Anaxyrus*] *cognatus*). A large fraction of the native prairie land cover has been converted into intensive cultivated cover types, supporting much of Canada's food production through cultivation. While this has contributed significantly to the regional economy, it has led to large-scale loss of native prairie habitat. An ecosystem that was once found across thousands of square miles of southern Canada has been steadily lost, leaving only a fraction of its original extent. The township and range grid that structured the European expansion across the prairies has led to a highly fragmented landscape, crisscrossed by roads and other linear infrastructure. Disturbances lead to challenges in the remaining native prairie landscape. Maintaining a functional and sustainable ecosystem in these lands requires that we seek to avoid further disturbance on lands with high conservation value and ensure mitigation efforts reduce the impact of disturbances that cannot be avoided.

Habitat fragmentation, habitat isolation, and barriers to movement (e.g. fencing, roads) are all conservation concerns for native and endangered species in this transformed landscape. These conservation concerns are recognized by the Prairie Conservation Forum and led to the production of the first Prairie Conservation Action Plan (PCAP) in 1988. The 2016-2020 PCAP (PCF 2016) recognizes the importance of achieving a balance between human and ecological values and functions, with an overarching vision where "the biological diversity of native prairie and parkland ecosystems is secure under the mindful and committed stewardship of all Albertans". To achieve this Vision, the PCAP identifies three main outcomes: 1) maintain large native prairie and parkland landscapes 2) conserve and connect corridors for biodiversity 3) and protect isolated native habitats for Alberta's Prairie and Parkland ecosystems.

Maintaining habitat connectivity is an important, but not the only, consideration to ensure movement and genetic diversity between otherwise isolated native habitats and populations. Conserving and connecting corridors for biodiversity is the focus of this literature review, while maintaining large native prairie and parkland landscapes and protecting isolated native habitats for Alberta's Prairie and Parkland ecosystems are integral components that will be addressed further in other reports and studies supported by the PCF.

Three key themes throughout this document directly support and stem from the strategic approaches and actions of the PCAP in relation to connectivity. They are:

- What are the key habitats that need to be connected?

- What factors or habitat elements facilitate movement?

- What are barriers to movement and how can the barriers be mitigated?

The purpose of this review is to provide a strong understanding of these topics for the Prairie Conservation Forum, its member organizations, and landholders to form a foundation from which to build their capacity to achieve the Vision and Outcomes of the 2016-2020 PCAP.

As species movements and responses to the landscape are highly idiosyncratic, it is important to stress that the strategies and recommendations which may improve connectivity for one set of species may have little impact on other sets of species. A fulsome discussion of connectivity from the perspective of all species found in the prairie region is beyond the scope of this report, due to the high degree of variation in the behaviour patterns of individual species. With this in mind, the report focuses on birds, reptiles, amphibians and mammals, with a high-level discussion of plants. Insects, as they are highly associated with particular plant communities which serve as their habitat, are outside of the scope of this document. Throughout this document, specific descriptions of the behaviour and ecology of individual species should be thought of as unique examples, rather than typical responses.

2.   The Importance of Connectivity

Alberta's prairie landscapes are facing conservation challenges associated with anthropogenic driven land-use conversion. Challenges include increased habitat loss and isolation of native prairie habitats due to fragmentation. These changes disrupt the functioning of previously contiguous landscapes and can result in reduced biodiversity, population stability (e.g. Fahrig 2002), genetic diversity (e.g. Vranckx et al. 2011), and dispersal ability (e.g. Holderegger and Di Giulio 2010).

Functioning landscapes support the ecological flow of energy, materials, and organisms at multiple spatial and temporal scales (Forman 1995). This can refer to the exchange of hydrological flow, sediment exchange, and nutrient cycling; the daily and seasonal movements of animals within home ranges; dispersal and genetic interchange between species; and long distance range shifts of species, such as in response to climate change (Planning Rule; USDA 2012).

The primary purpose of connectivity planning is to maintain, improve or restore connectivity to support ecological flows. Flow from a species perspective applies to the movement of organisms and gene flow (e.g. in the form of reproductive materials such as pollen), which can ensure movement and genetic diversity between otherwise isolated native habitats and populations. Populations that become isolated can be prone to local extinction and rely increasingly on rescue effects from colonization and recolonization events to maintain their populations.

There are two types of connectivity: structural and functional. **Structural connectivity** represents the physical connectedness of habitat patches in the landscape (Tischendorf and Fahrig 2000; Taylor et al. 2006), which is a function of habitat configuration (spatial arrangement of habitats) and composition (such as grassland, coniferous tree cover, agricultural fields, urban areas, etc.). Structural connectivity can change because of anthropogenic (e.g. land-use conversion; **Section 3.2**) or natural drivers (e.g. natural disturbance regimes). Since structural connectivity ignores species behaviour and/or dispersal ability, the structural connectivity of grassland habitats, for example, will be the same regardless of the specific species.

Functional connectivity considers a species' resource requirements (e.g. food, shelter, mates) throughout its life cycle and its ability to disperse between habitat patches (Taylor et al. 1993; With et al. 1997). It is influenced not only by landscape structure, but also by species' dispersal abilities or behaviour associated with environmental and biological seasons, life stages, and/or climate change. Two species with different life history requirements and abilities to perceive and move through the landscape will experience different degrees of functional connectivity, even in the same landscape.

The difference between functional and structural connectivity is least evident when considering species with limited dispersal ability or strong aversion to human disturbances (e.g. plants without airborne seed dispersal which are greatly constrained by unique growing conditions, forest-interior species with strong aversion to exposure, or shy species that avoid areas of human activity). For these species to experience a connected landscape, they require a landscape with a high amount of structural connectivity (i.e. well-connected forest patches, extensive grassland areas, hydrologically connected wetlands, or undisturbed riparian corridors, depending on the species).

For other species, which are more able to tolerate human disturbance, or move through a wide variety of habitats (e.g. deer, plants with short-range wind dispersed seeds, etc.) structurally disconnected habitats become reachable and functionally connected, provided the habitats are not separated by long distances. For habitat generalists (who can survive in a wide variety of land covers) or long-range dispersers (such as birds, black bears, and coyotes), much more of the landscape is accessible, allowing for greater ecological flow across the land, despite varying land covers and conditions. However, even for these species, certain land cover types may prove a barrier (high-traffic roadways, high fences, areas with extensive light pollution or other disturbances such as noise, or urban areas with active wildlife control measures).

The challenge and strength of connectivity as a concept is that it is not static. It is dynamic over scales of time and space (Taylor et al. 2006). The scale at which a species' interacts with the landscape is characterized by the species' dispersal ability and size, which can change depending on the species' *behavioural plasticity* in response to a changing environment (e.g. increased dispersal ranges of swift foxes in the winter due to a lack of resources) or morphological changes associated with life cycle stages (e.g. increased dispersal ability, size, and resource requirements transitioning from an aquatic tadpole to an amphibious frog).

Connectivity planning and management is widely accepted and applied by conservation biologists, planners, and land managers. It provides a framework within which the functionality of large landscapes can be maintained by conserving a network of habitat patches and connective corridors.

The success of this can be attributed to an emphasis on integrating multiple spatial and temporal scales, targeting multiple ecosystems and species, and prioritizing critical areas for conservation and management (e.g. GNLCC, Strategic Conservation Framework (Chambers et al. 2013); Natura 2000 (Sundseth 2008).

2.1   Habitat Networks

A habitat network is a system composed of habitat patches, corridors, and the matrix. **Patches** are remnant native or natural habitats that provide a species with its resource requirements throughout its life cycle. Natural areas that are critical for species persistence or to maintain biodiversity are termed "core" habitats, and they are typically embedded within the matrix. The **matrix** is the surrounding landscape of unsuitable or less suitable habitats composed of semi-natural to non-natural land cover types. It can have varying degrees of hospitality for a specific species or taxonomic group. Depending on various species-specific traits, including species sensitivity to noise and other disturbances, dispersal ability, and behavioural plasticity, the matrix is more or less easily traversed to access suitable habitat patches (e.g. dispersal can be active: flight, walking, swimming, or passive: wind, water, or animal vector). **Corridors**, the focal point of this review, are links of habitat that allow facilitated movement through the matrix to access suitable habitat patches.

2.1.1 Habitat Patches

2.1.1.1 Critical Habitats

Critical habitats are essential to sustain populations of native species in the landscape. Sometimes referred to as 'core areas', these are frequently focused in areas with undisturbed natural land cover, often the only natural cover remaining in highly disturbed landscapes. They bolster the overall biodiversity of the landscape by providing breeding habitats, important stopover habitats, and refuge from predation.

In the prairies, critical habitats are typically identified to include waterfowl breeding areas with international significance and breeding habitats for any species with >10% of its global breeding range in Alberta (ABMI 2009 in Shank 2012). Various organizations have identified critical habitats in the region including Northern Great Plains Priority Landscapes (Forrest et al. 2004; Schrag 2011); Areas of Concern (Weiler 2011 and AWA 2015); and wetland Target Landscapes (PHJV 2014).

Nationwide, coarse-fine filter approaches are used to identify ecosystem and species-specific habitats for priority areas that are important at regional and local scales (O2 2015). At a regional scale, critical habitats are typically examples of large landscapes that are priorities of regional and/or international importance. At a local scale, fine-filter priority areas identify species-specific habitats, such as sand dunes that sustain populations of the Ord's kangaroo rat (*Dipodomys ordii*; Environment Canada 2012). Species that are often targeted at a fine scale include species at risk, of special conservation concern, rare species, and endangered species. Critical habitats of rare species require their own evaluation, since methods and approaches applied for multispecies conservation are at too coarse a scale and may overlook these fine-scale habitats.

2.1.1.2 Isolated Habitats

In the prairies, the landscape is highly fragmented. Over a relatively short period of time, native habitat patches have become isolated in a matrix of cultivated and anthropogenic land uses.

Functional habitat isolation is the degree to which habitats become inaccessible due to the hostility of the matrix, barriers, or being beyond a species' dispersal ability (Ricketts 2001). Isolated habitats are physically or functionally disconnected from other surrounding habitats and/or a larger network.

This isolation can lead to undesirable effects including declining population viability, genetic diversity, and biodiversity; inbreeding; and local extirpation. The Greater Prairie-Chicken (*Tympanuchus cupido pinnatus*), for example, was threatened by population isolation and became extirpated from not only Alberta, but also Canada. Small populations of Greater Prairie-Chicken that still exist in the U.S. are considered isolated when separated by 10-20 km of unsuitable habitats (Robb and Schroeder 2005) and require habitat corridors to restore connectivity and mitigate negative effects. Populations that become isolated can also become dependent on rescue effects from immigrants of neighbouring populations to decrease their extinction risk by enhancing the gene pool of the local population (Hanski 1998). In Canada, the nearest neighbouring Greater Prairie-Chicken

populations were located too far away, more than 100 km, to be rescue. Moreover, re-colonization of suitable yet vacant habitats in Canada is currently improbable (COSEWIC 2006).

The prairie landscape contains larger habitats that are functionally isolated and numerous small pockets of habitat scattered throughout the landscape; habitats that, prior to the settlement of homesteaders in the early 1890s, were part of contiguous grasslands. Some remnants may have been left uncultivated due to the inability of agricultural machinery to cultivate steep topography (e.g. steep ravines and coulees, steep depressions), raised and rocky mounds, wetlands or waterbodies, and some corners of rectangular-shaped properties.

Isolated habitats, depending on their size and quality, may support local populations by acting as habitat refugia, areas which provide shelter from predation or other mortality events that may be experienced in the broader landscape. Without these refuges, populations of native species will often suffer loss at a greater rate than their reproductive strategies can accommodate, leading to local extinctions.

The capacity of these isolated habitats to support viable long term populations is species-specific. In some instances, small clusters of habitats may be grouped within reachable distances so that they function as a well-connected complex of habitat, isolated by the surrounding land cover from other habitats in the region. Some habitats may also only be seasonally isolated as a species' life cycle requirements and dispersal strategy change (e.g. stop-over habitats, breeding habitats). Some landscapes can be highly fragmented by river systems in the summer months, but freely traversable during the winter.

2.1.2 Corridors

Although the terms connectivity and corridors are often used interchangeably, they are not synonymous. Connectivity is the degree to which habitats or a habitat network, are connected by corridors functionally or structurally (also measurable as a metric), whereas a corridor is a component in this network that contributes towards connectivity. To clarify, adding a corridor, for example, will increase the degree of overall network connectivity or ecological flow.

Corridors can be present as contiguous linear features on the landscape (e.g. riparian corridors) or as a series of patches that act as stepping stones between habitats — stepping-stone corridors. Habitat patches can simultaneously facilitate movement as part of a corridor and provide habitat at different scales for different functions (e.g. habitat for dispersing species or corridor dwellers).

Corridors can also provide a variety of ecological functions acting as habitats, conduits, filter/barriers, sinks, and/or sources, depending on scale and species (USDA 1999). Critical corridors sustain movement between populations and reduce the risk of mortality by providing safe passage through the matrix. However, some unintended anthropogenic corridors can act as ecological traps. For example, in the winter, snow free railway tracks facilitate pronghorn movements; however, during periods of deep snow, pronghorn can become trapped at ditches or on the tracks by fencing and high snow banks (Gates et al. 2012). Many species can be funneled in less apparent ways (e.g. attractive vegetation, ease of movement) into areas of lower habitat quality and high mortality risk. The Ord's kangaroo rat, for example, can be attracted to disturbed linear features while dispersing along natural corridors, leading to colonization of low quality "sink" habitats, where their survival is reduced (Environment Canada 2012).

There are different types of corridors associated with a species' seasonal range of movement. Landscape scale macro-corridors are associated with long-range dispersal movements and migrations and home-range scale micro-corridors are associated with localized or commuter movements (Forman 1995; Way and Eatough 2006; Lamy 2015). Great Plains piping plover (*Charadrius melodus circumcinctus*) populations, for example, can migrate up to 1500 km (Haig and Oring 1988b) from their wintering grounds in Mexico to their breeding grounds in Alberta, using the Atlantic migration flyway (a macro-corridor) to disperse. However, once at the breeding grounds, the Great Plains piping plover occupy small ranges, flying short localized distances (~475 m Haffner et al. 2009) to feeding habitats. Furthermore, there are species-specific characteristics that influence the appropriate design of corridors to ensure their use (e.g. width, composition, configuration, line of sight, cover characteristics). These characteristics influence how a corridor is perceived by the animal, whether it feels sheltered, exposed, whether it can detect predators, and whether predators can reach the animal. The challenge when designing and implementing corridors in the landscape is to balance these factors, making the corridor of use to as many species as possible.

Together, patches and corridors form an interconnected network that supports the persistence and movement of multiple species and ecosystems. Multiple corridors provide resiliency in the landscape, allowing other routes to take up slack when one is lost. While the removal of a single corridor may reduce ecological flow across the

landscape, it will not be lost altogether due to the availability of other routes. When all movement through the landscape must follow a single path, any event which inhibits this movement can have a disproportionate effect (a predator may begin preying on individuals moving through that single corridor, a human disturbance may be introduced such as a new roadway or fenced structure, or a flood or sudden snowstorm may prevent passage).

2.1.3 Matrix

Another common term in many studies of connectivity is that of the 'Matrix', the inhospitable area outside of what a particular species considers as habitat. As with the notion of 'corridor', this term is also falling out of use, as it has been recognized to paint an unrealistically stark dichotomy between land cover types, which is often not representative of how animals view the landscape. While the matrix is not considered a habitat patch, it is not necessarily a wasteland either. Although it provides fewer ecosystem services (O2 2008a) and generally poses increased risk of mortality for travel, the matrix can be relatively hospitable or benevolent with low mortality risk. It can however act as an "ecological trap"; grizzly bears, for example, have their core habitats in forested areas; however, as they traverse through agricultural landscapes, the matrix of southwestern Alberta, they are attracted by grains, feed, and livestock (AEP 2016; Northrup et al. 2012). Improving the buffer between highly disruptive anthropogenic land uses and higher value conservation lands will greatly improve the ability for species to move through the matrix into their preferred habitats. This can increase biodiversity and improve landscape connectivity by improving dispersal, decreasing mortality, and increasing access to resources, thereby offsetting the extinction risk of isolated habitats. Species that benefit most from this are those with intermediate dispersal abilities (Donald and Evans 2006) such as reptiles, amphibians, and some birds, mammals, and invertebrates.

2.2   Landscape Permeability

The prairie region is composed of a multitude of land cover types and uses. Landscape permeability is a function of species' willingness to cross inhospitable terrain, risk of mortality, and ability of movement (Zeller et al. 2012). The "invisible mosaic" refers to a species' movements in relation to land uses that are not as apparent to the eye or to remote sensors as types and structures of land cover (Fahrig et al. 2011). The invisible mosaic includes land uses such as hunting, recreation, traffic, light, industrial activity, and territoriality.

Some species are less sensitive to disruptive land uses or may habituate to these disturbances. Depending on their sensitivity, they can either continue to inhabit the area with little change to their movement patterns or adapt their behaviour to avoid or pass through the area with less frequency during peak activity periods.

2.2.1 Movement Inhibitors

A barrier can present a physical barrier to movement and/or a very high risk of mortality to cross. Barriers in the landscape can vary from absolute to partial. Absolute barriers are considered completely impermeable because the barrier is not physically traversable and/or survival is improbable (e.g. for pronghorn, woven and barbed-wire fences with low bottom wires result in potential entanglement, impact injuries, or death; Gates et al. 2012).

Partial barriers filter or allow some movement, but are still difficult to cross, which can impact individual fitness and survival (e.g. finding mates and resources, escaping predators). Major transportation corridors, for example, are partial barriers for pronghorn as they allow some movement through, but can impede movements by up to 10 days until pronghorn attempt a crossing at a select location. In addition, fences, including pasture fencing, are also partial barriers as they can limit the ability of pronghorn to freely move across the landscape, while also having indirect negative effects (Jones 2014).

In the prairies, there are several potential barriers to terrestrial movements, such as roads, railways, fences, rivers, and water bodies. However, this perspective is species-specific; the degree to which a species interacts with its environment is often characterized by its dispersal ability and size. For example, to an aquatic or amphibious species, rivers and water bodies are highly permeable areas, and dams, weirs, berms, and culverts are potential barriers.

For many breeding grassland birds, raptors, songbirds, bats, and over-wintering birds (AEP 2011), wind turbines present a connectivity challenge. Migratory and resident species can be imperiled or can collide with the blades of these structures while travelling through aerial migration routes or during localized aerial movements (AEP 2011). Wind development is not limited to the construction of turbines, but also requires associated access roads and disturbance of native vegetation. This can further fragment the landscape, resulting in invasive species

spread, edge effects, habitat loss, and potential ecological traps for native species that establish on or require disturbed grounds. Mitigating the impacts of the ongoing rapid development of wind power will be critical in the future (e.g. Bradley and Neville 2011; AEP 2011). Our understanding of the impacts of these structures is incomplete, and ongoing research will help to understand how their design and placement influence their impacts on wildlife movement (Nelville 2017).

2.3   Scales of Interaction and Perception

A fundamental factor in assessing landscape connectivity for a species is the scale at which it perceives and interacts with the surrounding environment (D'Eon et al. 2002). Organisms which make only short-range movements across the land have a reduced perception of their surroundings, and what humans would see as a small break in land cover may be an impassable divide. More mobile species may have a greater perception of their surroundings, and so be aware of other potential habitats across the landscape. However, their ability to reach these other habitats is impacted by the nature of the surrounding land cover, while some species are bold, and willing to cross into inhospitable terrain, others are more sensitive to disturbances such as noise and light, and may be unwilling to cross even short distances to reach new habitat. As species display behavioural idiosyncrasies and varying responses, deriving consistent recommendations is problematic. Recommendations for improvements to connectivity in a landscape require explicit understanding of what species are likely to use that landscape.

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3. A Changing Landscape: Alberta's Native Prairie and Parkland Landscapes

The prairies and parklands of Alberta are part of the North American Great Plains — a prairie biome that extends continentally from southern Alberta to northeastern Mexico. Most research projects in these regions are independent, short-term, and do not contribute towards a broader regional assessment of biodiversity (Holroyd 2011). A network approach to ecosystem and species management and planning follows the idiom "Think Globally, Act Locally" by identifying the components and interconnections that constitute the three pillars of the PCAP: 1) maintaining large native prairie and parkland landscapes, 2) conserving and connecting corridors for biodiversity, and 3) protecting isolated native habitats. Built on a foundation of knowledge of ecological processes and functions, these pillars support the overarching assembly of critical landscape elements (cores and corridors) required to build a sustainable and resilient landscape.

To identify critical habitats and corridors that require connection, it is necessary to understand current the **landscape integrity** and the role of isolated native habitats and the matrix. Resiliency incorporates the concept that the landscape is dynamic — changing over time in response to **landscape stressors**. To anticipate the importance connectivity has for species responding to change, it is important that we understand these dynamics and how they affect ecological processes and patterns.

3.1 Landscape Integrity

Alberta's prairie and parkland regions (156,318 km^2; **Figure 1**) provide globally unique ecological systems that are only found within the North American Great Plains. These ecosystems are vital contributors for the regional economy, providing many significant ecological services including nutrient cycling, pollination, habitat for livestock grazing and crops, recreation, and climate regulation (Samson et al. 2004). They are also vibrant cultural landscapes, providing biocultural diversity, forming an integral part of the identity and wellbeing of First Nations and ranching communities, as well as avid outdoor recreationists, nature watchers, hunters, and anglers.

The region consists of grassland, woodland, and wetland ecosystems (Riley et al. 2007) and has historically evolved within a natural disturbance regime of drought, flood, fire, and grazing (Bradley and Wallis 1996). Maintaining these processes and connectivity within a natural range of variation is critical to maintain biodiversity (CBFA 2016). Presently, the region has become extremely fragmented and highly disturbed with 63.1% of the area dominated by non-native agriculture (55.2%), transportation (2.7%), energy (2.5%), and urban, rural, and industrial areas (2.3%), with only 37% remaining as native vegetation (ABMI 2015). This is within a critical range, between 20-50%, where various studies have found that the impacts of fragmentation become more prevalent (O2 2008b). As one of the most endangered ecosystems in the world (ABMI 2015) these native grasslands have the highest risk of biome-wide biodiversity loss (Roch and Jaeger 2014). Fragmentation and habitat loss are the primary contributors to population decline of native species such as Baird's sparrow and Sprague's pipit (ABMI 2015). Approximately 80% of Alberta's species-at-risk and 25% of rare plants are associated with these native grasslands (ABMI 2015).

There are few native grassland landscapes left in the North American Great Plains that are large enough to sustain a full range of native biodiversity and ecological processes (the Grassland and Parkland Region is currently 57,061 km^2; ABMI 2015). In temperate grasslands, greater biodiversity on the landscape generate ecosystems that are more resilient to landscape stressors (e.g. land use conversion, climate change, invasive species; Tilman et al. 2007; Hautier et al. 2015; Wang et al. 2016). Conserving the remaining large tracts of prairie offers the best chance at maintaining the underlying ecological processes that support patterns of biodiversity at both local and regional scales (Samson et al. 2004).

At a regional scale, the remnants of native prairie landscapes with high biodiversity intactness and high landscape integrity form a visible structural network (**Figure 2**; ABMI 2015). Trees and shrubs follow riparian connections between largely intact blocks of native prairie; sand dunes, badlands, wetlands, and lakes are interspersed patches of habitat; and at a more local scale, smaller patches of relatively "isolated" native prairie emerge from the mosaic. As only 2,218 km^2 (1.4%) of this region are designated as protected areas (ABMI 2015), maintaining strong connections between these core habitat areas is essential for maintaining healthy populations both within and around protected lands. Without adequate amounts of undisturbed natural habitat outside of the few formally protected areas, the decline of the species that make up the Great Plains ecosystem is likely to continue.

The Grassland and Parkland Natural Regions are composed of six Provincial Subregions that are combined into four Ecoregions at the National level and, at the International level, two Ecoregions that span into the United

States. The Rocky Mountain Natural Region, although predominantly composed of coniferous and mixedwood forests at lower elevations, also contains grasslands mainly within the valley bottoms of the Montane Natural Subregion (MNSR) and to the east within Cypress Hills (a geographically isolated MNSR outlier; NSR 2006). These Canadian Subregional and Ecoregional units are formed by geographically similar groupings of climate, physiography, vegetation, soil, wildlife, and landforms. These Subregional divisions influence bird and plant abundance, even more so than human footprint (Huggard et al. 2015).

At the Continental level, these divisions represent coarser groupings of similar climates, landforms, and biological diversity — most Canadian Subregions are within the Northwestern Glaciated Plains. These ecological units are often used at different scales for regional and meso-regional planning, enabling transboundary partners, at different scales within the same units, to work collaboratively towards achieving shared goals and priorities.

| International (Biome)	Continental (Ecoregion)	National (Ecoregion)	Provincial (Subregion)
North American Great Plains	Aspen Parkland/ Northern Glaciated Plains	Aspen Parkland	Foothills Parkland
			Central Parkland
	Northwestern Glaciated Plains	Moist Mixed Grassland	Northern Fescue
			Mixedgrass
		Mixed Grassland	Dry Mixedgrass
		Fescue Grassland	Foothills Fescue
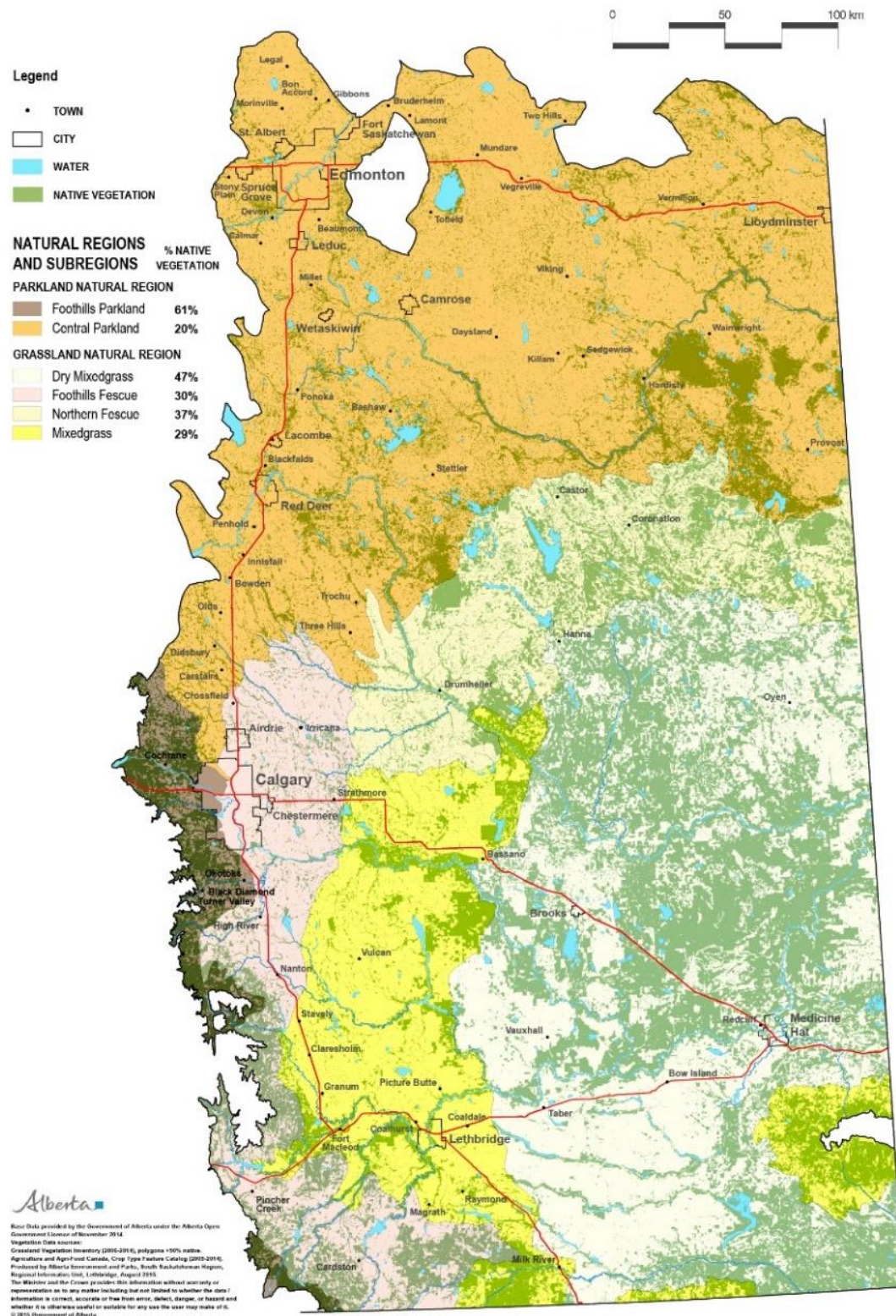
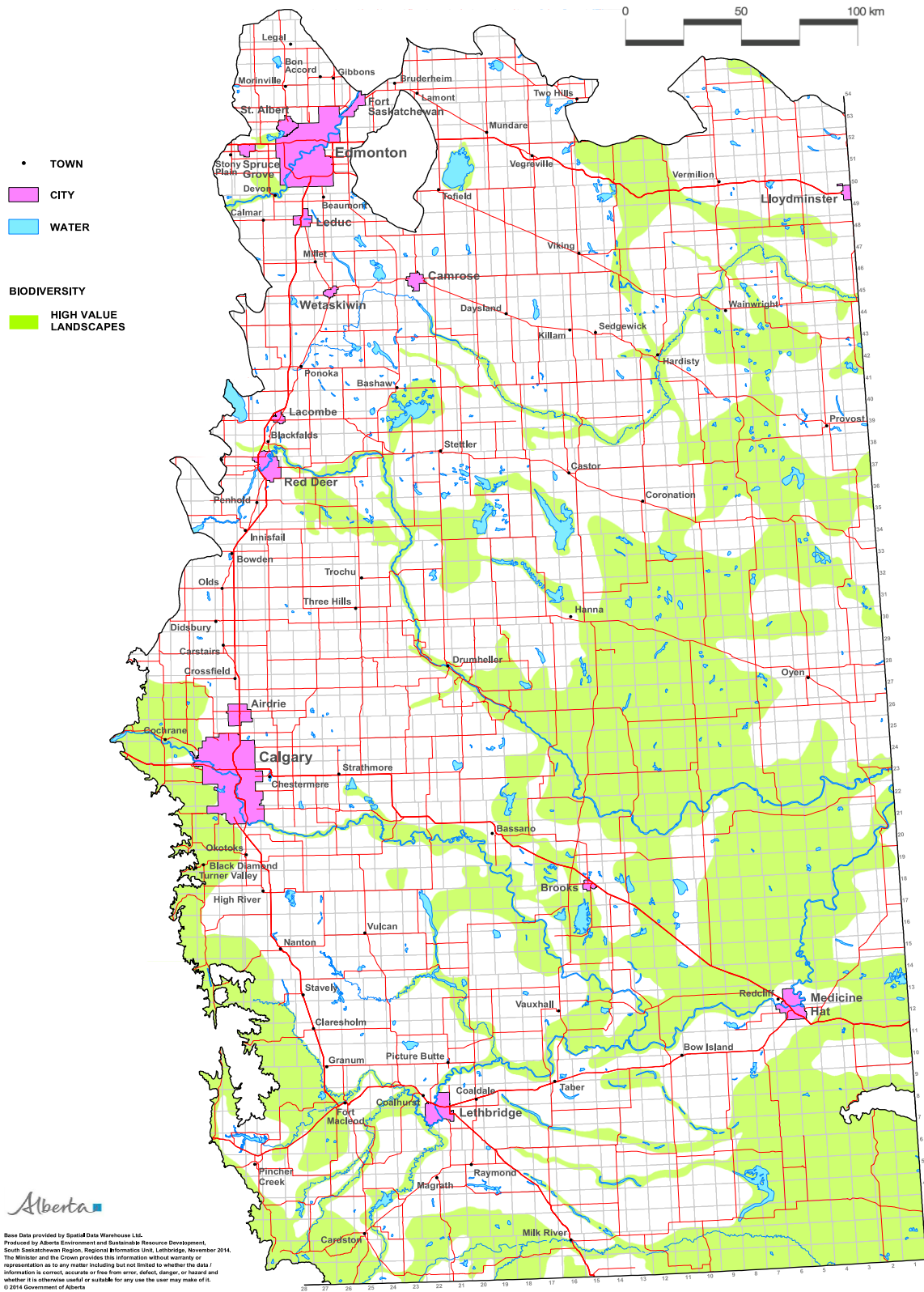Figure 1: Parkland and Grassland Natural Regions in Alberta

Figure 2: Landscape Integrity — High Value Native Biodiversity Landscapes

3.2   Landscape Stressors

Landscape stressors are drivers that can act independently or synergistically to alter landscape processes and patterns. The region consists of grassland, woodland, and wetland ecosystems (Riley et al. 2007), and has historically evolved within a natural disturbance regime driven by natural landscape stressors including drought, flood, fire, and grazing. The European settlement introduced a variety of additional stressors (such as road and railway development, landscape conversion to cultivation, urban and industrial development), and a reduction in numerous natural stressors (through irrigation, fire suppression, and loss of natural grazing species). Many prairie species have evolved with these disturbances and some have even become dependent on them for regeneration or survival (Bradley and Wallis 1996). As the nature and frequency of these stressors has changed, an associated loss in prairie biodiversity has occurred.
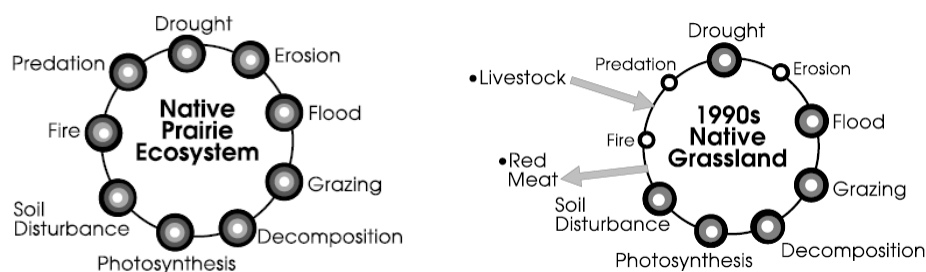

Fig. 3 Disturbance regimes in a) historic and b) more recent native prairie ecosystems (Bradley and Wallis 1996).

3.2.1 Natural Disturbance Regimes

There is little historical evidence of the natural range of variation of **fires** in the prairies — their size, intensity, and frequency — but it is thought that there were frequent small, fewer medium, and infrequent large fires. Fires are initiated by humans or by lightning strikes. However, since the 1900s, people have suppressed fires, resulting in a significant decrease in the size and occurrence of burned patches, which causes changes in vegetation composition and structure, insect populations, and soil productivity (Kerr et al. 1993).

Grazing approximates some of the effects of fire by preventing expansion of shrublands and woodlands into grasslands and can work together synergistically (e.g. Baird's sparrow and Sprague's pipits were more abundant at sites that were burned and grazed; Richardson et al. 2014). Historically, bison moved in large herds (>10,000) with erratic migration patterns, but when present, they put grasslands under intense grazing pressure. Birds and mammals have evolved and adapted along a gradient of increasing grazing intensity and timing. Some species are primarily found in heavily (e.g. McCowan's Longspur, Ferruginous Hawk), moderately (e.g. Long-billed Curlew, Savannah Sparrow), or lightly (e.g. Baird's sparrow, Sprague's pipit) grazed areas, but most bird, mammals, and plants are adapted to moderate levels of grazing (Bradley and Wallis 1996) and many decline with overgrazing (Saunders 2001; see **Fig. 3** as an example).

Currently, the native grasslands are grazed by cattle. Modifying grazing pressure by cattle through range management can create a heterogeneous landscape, which promotes biodiversity and ecosystem productivity. In some cases, this is more influential for improving ecosystem productivity and resilience than directly increasing biodiversity (Vogel et al. 2012).

Flooding frequency and intensity influences the natural propagation of many riparian plant species, often reducing the likelihood of successful reproduction. When a dam is placed on a river, it results in increased frequency and intensity of short-term floods in response to human-directed changes to the flow regime (as water levels are controlled to allow for irrigation and other uses), while resulting in decreased intensity of long-term floods (as reservoirs allow for increased storage times of large rainfall events). Therefore, the overall range of variation in water levels decreases. Plains cottonwood depends on long and short-term floods within a normal range of variation to create conditions for seed establishment. If the range of variation is reduced so that floods are not as large, cottonwood forests do not regenerate. As this process is increasingly understood, however, efforts have been made to manage water levels on dammed-rivers to allow for flood regimes which more closely mimic those seen on uncontrolled rivers in the foothills and prairie. The Oldman River is an example of a successful reintroduction of a more natural flood regime, with longer inundation periods following high water

flows, which has led to a rebound in previously declining cottonwood populations downstream of the dams (Rood personal communication 2016).

On the other extreme, **droughts** can introduce rapid changes to landscapes as vegetation declines, and soils become more susceptible to disturbance, loss or conversion (such as the spread of sand dunes). As vegetation declines, wind and erosional processes lead to increased active sand dunes. Some prairie species are dependent on these active sand dunes as critical habitat (e.g. Ord's kangaroo rat) and fire and intense grazing can help reduce the stabilizing effect of vegetation on sand dunes. Changes to land and water use, as well as climate shifts, may lead to changes in this behavior.
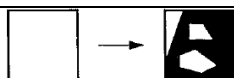
The following three anthropogenic stressors are singled out due to their importance (ABMI 2015; Schneider 2014) and alignment with ongoing transboundary landscape conservation initiatives in this prairie biome. For climate change adaptation, improving landscape connectivity is the most frequently recommended strategy to sustain biodiversity (Heller and Zavaleta 2009).

3.2.2 Land-Use Conversion: the Creation of the Matrix

Historically, the main driver of habitat loss and fragmentation in the prairies is cultivation, the development of the road network, and urbanization (ABMI 2015). Overgrazing, invasive species, industrial development (well-sites and windfarms) also contribute to loss of habitat and ecological function; linear features such as pipelines, roads, and access roads associated with these disturbances also contribute to extensive landscape fragmentation (Sinton and Pitchford 2002).

Fragmentation is a process that goes through five phases (perforation, dissection, subdivision, shrinkage, attrition; **Table 1**) as the landscape converts from a natural to a human-dominated landscape (Forman 1995; Jaeger 2000; Fahrig 2003). Perforation is often the first step in fragmentation, as pockets of human disturbance occur within continuous natural land cover. Dissection is another commonplace disturbance pattern in the prairie, as road networks bisect existing patches of vegetation. Subdivision occurs as the human footprints become the dominant land cover, leaving islands of natural cover surrounded by disturbed landscapes. Over time, these remnants shrink, or are lost altogether, resulting in lands fully dominated by human impacts.

Table 1: The five phases of landscape fragmentation.

1. Perforation		Starting with contiguous landscape, holes are formed.
2. Dissection		Starting with contiguous landscape, the area is subdivided by equal width lines.
3. Subdivision		Starting with contiguous landscape, concurrent habitat loss (Shrinkage) and subdivision of the landscape (Dissection) results in disjunct fragments.
4. Shrinkage		Starting with a subdivided landscape, remnant patches continue to decrease in size.
5. Attrition		Starting with a subdivided landscape, patches, and corridors disappear.

As the landscape transforms, changes in the heterogeneity of land covers/uses can greatly influence the movement of species (Theobald 2006). Typically, this land-use conversion results in a decrease of native populations, but there are exceptions including the Long-billed Curlew, Six-dimpled Northern Mite, and Cuspidate Earth Moss — species such as these may take advantage of the changed landscape structure through linear features and edge habitats. However, even in an already highly converted landscape, providing a heterogeneity, or mosaic, of land uses and vegetation (structure and composition) allows some species to thrive. The burrowing owl (*Athene cunicularia hypugaea*), for example, directly benefits from heterogeneous vegetation

and intensities of livestock grazing, which allows their prey, small mammals, to proliferate (Marsh 2012; Fisher and Baine 2014). Management and mitigation of the matrix at multiple scales is key to restoring and maintaining connectivity and native populations, since, as is the case globally, protected habitats will only ever form a portion of a habitat network (Franklin and Lindenmayer 2009).

3.2.3 Climate Change

Climate is one of the primary drivers of ecosystem patterns at the regional scale and is a strong determinant of Subregion type. Climate change has the potential to shift the current boundaries of these subregions, primarily following changes in moisture and associations with rising elevation (Schneider 2013). In southern Alberta, ecosystems would transition into those typically found in central and eastern Montana. Historically, this level of change occurs within the natural range of variation.

Under a model representing a maximum amount of change, ecological transitions become harder to predict. Inactive sand dune areas, currently stabilized by vegetation, can be become active again. Wetlands would experience regional drying, where average water levels would decline and seasonal wetlands would remain dry for longer periods. Local plant community types would favour local species and exotic immigrating species that are better adapted to hotter and drier conditions (Schneider 2013).

It is important to anticipate the effects of climate change for vulnerable species (especially for those that are not currently considered at risk), since species-at-risk have greater vulnerability to climate change than secure species (Shank and Nixon 2014). Identifying and protecting habitats that are stable under climate change that continue to support biodiversity — climate refugia — will play an important role for protection of these vulnerable species (Schneider 2014; Beier and Brost 2010). In Alberta, species in the Grassland Natural Region are expected to have the most difficulty shifting ranges due to anthropogenic barriers to dispersal. It is imperative that wildlife movement to track changing habitats is supported, and that the remaining movement paths are not further disturbed.

If habitat is available and dispersal is possible, most species can be expected to shift their ranges in response to climate change. Less mobile species and species vulnerable to anthropogenic barriers will require creative design to assure connections to suitable habitats. Alberta's amphibians have been assessed as highly vulnerable to climate change and birds as the least vulnerable (Shank and Nixon 2014).

In some cases, intervention may be required to assist migration for less mobile species, such as the rare plants Northern Blazing Star (*Liatris ligulistyli*) and Long-Leaved Bluets (*Houstonia longifolia*; Pederson et al. 2014). Looking beyond Alberta's boundaries, novel species typically found in the northern United States, may now be shifting their ranges into Alberta. To understand the future shift in species habitats, detailed ecological disturbance and land-use modelling are required to downscale regional climate change predictions (Shank and Nixon 2014).

3.2.4 Invasive Species

Invasive species are non-native species that present a significant threat to integrity and biodiversity by reducing the uniqueness of ecosystems at large spatial scales (Crooks and Suarez 2006). Invasive species are introduced both intentionally (e.g. agriculture, ornamental, medicinal) and unintentionally (e.g. contaminants in seed, in soil, with machinery, through recreation; CFIA 2008). The most widespread and abundant invasive species in Alberta are vascular plants such as Canada thistle and smooth brome, but also terrestrial vertebrates (e.g. feral cats, house sparrow); invertebrates (e.g. mountain pine beetle, seven-spotted lady beetle); aquatic organisms (e.g. brown trout, brook trout); and diseases (e.g. Whirling disease, West Nile virus, brucellosis; McClay et al. 2004).

Invasive plants, especially noxious weeds, are widespread in the prairies, even in native vegetation. The main mechanisms of invasive species introduction in Canada have been ornamental plants, contaminated plant products, and cultivated crops (CFIA 2008). Human footprint (i.e. cultivated crops and tame pasture, urban/industrial settlements and developments) is primarily responsible for rapid spread of invasive species, but overgrazing and linear features are also influencing this expansion into native prairie and parkland vegetation (Schieck and Huggard 2015).

Soft linear features (e.g. road margins, pipelines, power lines, seismic lines) and hard linear features (e.g. roads, railways) extensively fragment the landscape and can serve as corridors that propagate invasive species spread (soft linear features contribute more than hard features (Schieck and Huggard 2015)). From the perspective of

invasive species, this highly fragmented natural landscape is a well-connected system of highly suitable urban, industrial, disturbed, and agricultural habitats (Crooks and Suarez 2006). This is one reason why invasive species spread so readily: they respond well to the types of land cover which human use promotes, and their potential competitors do not. Human-mediated dispersal is a key factor in spreading invasive species across natural/anthropogenic barriers (e.g. mountain ranges, large water bodies, urban footprints) and into disconnected water systems (Crooks and Suarez 2006).

Generally, invasives have good dispersal ability, short generation times, rapid growth cycles, and are adaptive to a range of environmental conditions (Bradley et al. 2010). Climate change is expected to make conditions more suitable for a variety of invasives; particularly, giant knotweed (*Fallopia sachalinensis*), tamarisk (*Tamarix chinensis*), and alkali swainsonpea (*Sphaerophysa salsula*; Chai et al. 2014).

Widespread eradication of these plants is not feasible and management efforts should therefore focus on large tracts of intact vegetation that are insulated from invasion along the perimeter (Schieck and Huggard 2015). Preventing the establishment of new populations can help control already established invasive populations (Crooks and Suarez 2006). To make relatively intact native populations more resilient to invasion, it will be important to buffer and mitigate priority conservation areas from invasive populations introduced within the human footprint and any potential spread prompted by reduced habitat quality and disturbance associated with overgrazing or informal recreational trails (e.g. walking, biking, OHV).To prevent unintended facilitation of invasive species dispersal and expansion, habitats that are intended to maintain or restore connectivity for native species must be well managed to prevent invasives from establishing (Chai et al. 2014; Crooks and Suarez 2006). This can entail simple methods which restrict access or limit disturbances which might otherwise create suitable habitat for invasive species of concern, or more intensive efforts to monitor, exclude and eradicate invasives.

4.   A Lens into Prairie and Parkland Connectivity in Alberta

The grassland natural region represents 14.4% (95,565 km²) of Alberta's land area (Natural Regions Committee, 2006). Current efforts towards formal protection have resulted in only 1.29% of grassland ecosystems protected under legislation (Government of Alberta, 2009). In 1991, the Canadian Environmental Advisory Council (CEAC) recommended that a protected area should be at least 4,000 km² to effectively conserve biodiversity and wilderness. The existing grassland protected areas fall well below this mark with the average size among the different types being 21.02 km² (2102.21 ha), only 0.5% of the recommended size (ATPR, 2009). Invasive species, climate change, and land use conversion are the three main anthropogenic drivers that have shaped and driven the fragmentation of formerly contiguous native prairie habitats. In addition to these anthropogenic drivers, there are natural drivers that have exerted change on the landscape for millennia, shaping the ecological patterns and processes we still see today. Natural drivers include fire, drought, grazing, and flooding.

4.1   Human Impacts on Connectivity

As the dominant force for landscape change in the prairies, humans have a disproportionate impact on connectivity and population viability for prairie species. The anthropogenic footprint in the prairie ecosystems is immense, especially when considering the distribution of cultivation and the associated road and infrastructure network which stretches across the land. Direct mortality and habitat disturbance from human activity has disrupted the natural composition of prairie biodiversity, leading to a decline in the historic range extents of many iconic species. Land use conversion and fragmentation, coupled with active disturbances associated with human use, have rendered much of the land inhospitable for many prairie species.

The ABMI measures habitat fragmentation of native vegetation by calculating the effective mesh size of the Prairie Region. Effective mesh size is a measure of the size of native vegetation patches combined with distance to edge at a particular scale. Larger mesh size values occur in bigger native vegetation patches further from the edge of human footprint, whereas smaller mesh size values indicate smaller patches and more human footprint. The average effective mesh size of the Prairie Region is 5.0 km2 when linear features like roads are included as human footprint that divides native patches. The average effective mesh size in high quality prairie landscapes is 11.9 km2 compared to only 0.4 km2 in more disturbed landscapes, when linear features are counted as dividing native patches (ABMI 2015).

The prairie ecosystem has declined greatly since European colonization, and the associated spread of cultivated land uses. Human settlements, road development, and the extensive shipping of grains and seeds have led to widespread invasive species, replacing native species who are less adapted to human disturbances. Draining of wetlands, the tilling and flattening of large plots of land, and a repression of wildfire has led to loss of a wide variety of prairie habitats, making the remaining areas of natural, native vegetation incredibly important to preserve, to retain what few intact landscapes remain. Wildfire management, grazing operations, and pollinator services are essential components for the preservation of the prairie landscape. Land owners, stakeholders and land managers must work closely together to ensure that these factors are not further degraded by human activity.

4.2   Temporal and Spatial Connectivity

Temporal fluctuations in connectivity are observed at various scales:

- Moment to moment, as changing wind patterns impact flight paths, and changing traffic volumes make areas unexpectedly impassable.

- Across a single day, as available light, air temperature and other associated impacts of the diurnal cycle influence the behaviour of wildlife. Urban areas, major highways and centres of industrial development provide strong disturbance to this natural regime however, as bright, unconstrained artificial lights disrupt natural cycles.

- Across the seasons, as shifting light and temperature regimes become more extreme. As Alberta is a temperate province, day length is highly variable across the year, bringing with it a more narrow window of activity for those species with specific daylight requirements. This shift in the seasons brings with it more wholesale shifts in the landscape, as leaf-loss reduces cover in parkland, and blowing snows cover the prairie, and frozen lakes and rivers become easily passable. The occurrence of the Chinook works to

offset this seasonal impact, sporadically exposing the grassland for forage. Flooding events can also produce major changes to the permeability of the landscape.

- Over longer time periods, at shifting climatic conditions restrict or expand existing ranges, causing areas to become more or less hospitable over time.

Spatial variation in connectivity across the prairie is also high. While for the most part the township and range grid produces a uniform mesh of fragmented habitats, there are notable exceptions, such as the Suffield Armed Forces base, where large unbroken habitats are still found. Pockets of protected areas also exhibit varied land cover patterns, depending on their historic use. A chief factor driving the variation of connectivity through the prairie area is the hydrologic drainage network, which follows its own path through the landscape, providing connected reaches of riparian vegetation throughout the region. As one moves further west towards the foothills, the prairie pothole landscape provides another factor which has frequently stymied development, introducing natural patterning into the grid system. Other chief factors in the connectivity of the landscape is dependent on the location of major urban centres and other attractive nodes for human activity such as industrial processing centres and feedlots. Impedance of connectivity between these urban centres is substantially more disruptive than through the grid of rural access roads, due to greater traffic volume, more extensive lighting, and substantially more built features and amenities.

4.3   Structural Versus Functional Connectivity

As has been described above, the prairie landscape is highly fragmented with regards to structural connectivity: the road network is uniformly distributed across much of the landscape, and a large degree of land cover conversion has led to the loss of the prairie landscape. The degree to which this translates to functional loss of connectivity for a single species depends on how they view the landscape, how they move through it, and how sensitive they are to human disturbance, both temporary and permanent. For disturbance-averse species that require the absence of human activity, the remaining hard-to-reach patches of high integrity habitats are essential for their continued presence in the prairie landscape. For other species, the prairie remains a fundamentally connected landscape, but even these species suffer from mortality and degradation. The magnitude of human impacts on these lands mean that we have seen a wholesale reduction in individual populations, and a wholesale loss of biodiversity, compared to that existing a scant few centuries ago. It is essential to consider that not only the natural, but also anthropogenic drivers affect the configuration, structure and function of the habitats which remain. As the human footprint is unlikely to diminish over time, we must seek to minimize the impact of that footprint. It is also important to recognize that, at different life stages and seasons, different species may not require connectivity, but instead may benefit from or rely on either functionally or geographically isolated habitats. There are no easy quick fix blanket solutions to the problems of connectivity in the prairie landscape.

4.4   Research Gaps

There are various research gaps present, specifically within species assemblages or across taxonomic groups that are related to their rarity, highly localized nature, lack of technology for tracking, or lack of monitoring. There are several notable gaps in our current understanding:

Birds

- Full life-cycle movement patterns for birds, especially at overwintering sites.
- Habitat characteristics and movement patterns associated with stopover sites for grassland passerines.
- Identification and restoration of stopover sites that may be acting as ecological traps reducing survival and reproductive success at the breeding grounds.
- Importance of aerial habitats for birds, specifically the potential importance of aerial hunting habitats for raptors.
- Collision risk modelling of structures on the prairie landscape in relation to major migratory flyways to inform management and construction decisions.

- Importance and location of different stopover/staging sites for most birds.

Waterfowl

- Habitat associations of waterfowl with wetlands at local and regional scales at their breeding and overwintering grounds.

Plants

- The life cycle, life history, occurrence, and importance of connectivity for mosses.

- The spore, seed, and pollen dispersal abilities of vascular and non-vascular plants.

- The degree to which the reproductive method (i.e. asexual and/or sexual) and output of vascular and non-vascular plants affects their dispersal ability for range expansion.

- Availability of open habitats in the surrounding landscape suitable for establishment of new populations and their potential to connect isolated populations for different species.

Herptiles

- The effect of fire management on reptiles.

- The dispersal abilities of the Short-horned lizard.

Multispecies

- Identification of functional wetland networks at different scales for amphibians and birds to simultaneously understand the role of smaller more isolated wetland within the wetland network.

- The role, importance, and characteristics (e.g. vegetation, nutrient retention) of more hydrologically isolated wetlands and their relationship to sustaining amphibian and bird diversity through different life stages.

- The role (e.g. as refugia or ecological traps) and importance (e.g. for invertebrates or plants) of the numerous small, geographically isolated remnant native or natural prairie patches that are inaccessible for cultivation by modern agricultural machinery on private lands.

4.5   Potential Opportunities

- Growing recognition of the value of connected landscapes across the general populace makes connectivity programs easier to justify.

- Aging infrastructure across Alberta will provide amble opportunities to piggy-back improvements to connectivity alongside redevelopment.

- Shifts to alternative energy may see some existing oil and gas infrastructure phased out of use. Provided they are reclaimed to natural land cover types, this may be expected to produce improvements in connectivity of the landscape.

- Existing trial installations of solar and wind farm operations provide the opportunity to learn about their potential impacts on wildlife connectivity before such developments become more commonplace.

- Greater recognition by municipalities of their role in providing habitats and connected routes within urban areas. This may result in more awareness of the impacts of habitat loss due to large scale development.

5. Key Movement and Connectivity Characteristics for Prairie and Parkland Species

Conservation planning is dependent on understanding landscape integrity, landscape stressors, and the landscape requirements of species of conservation concern. Identifying key characteristics of species and ecosystems, including connectivity characteristics, is the basis of planning for a well-functioning natural landscape (Haber et al. 2015).

The species found in prairie landscapes exhibit a broad range of responses to the composition and configuration of land cover and human disturbance. There is a remarkable diversity of grassland birds, waterfowl, raptors, plants, small mammals, insects, and amphibians, some of which are present in highly localized and uncommon populations. The movement patterns of these organisms are similarly varied: some are wide ranging species that travel great distances, others are more restricted in their individual movements, and see shifts in range only across multiple generations. Some avoid human-dominated landscapes entirely, others are drawn to urban areas. Some are active in daylight, other nocturnal. The wide diversity of movement behaviours preclude a 'one size fits all' solution to ensure connectivity in prairie and parkland landscapes; nature is varied, and so too must our strategies for maintaining nature vary.

In the following sections, key connectivity characteristics for the following species assemblages will be reviewed: grassland birds, waterfowl, raptors, reptiles, amphibians, plants, small mammals, and large mammals. Conservation planning for individual species can be extremely complex, and therefore the focus will be on a smaller suite of priority (Endangered, Threatened, Sensitive, May Be At Risk, At Risk) or representative species and habitats within the grassland and parkland region.

BIRDS

Birds constitute a very broad category of organisms, exhibiting a diversity of body forms, behavioral strategies, and ecological niches. While some species spend their entire lives within the prairie ecosystem, the large majority are migratory species. Birds exhibit a variety of strategies to survive a cold climate. In Alberta, most birds migrate southward, but there are some that are resident species who shift their home ranges into areas that can provide resources during the winter. These birds fly hundreds or even thousands of kilometres from areas as far away as the Gulf of Mexico and northern Mexico through the midcontinental United States. Migratory connectivity is extremely important to consider for Albertan birds at a continental scale, as successful conservation may be undone by impacts occurring in any areas these birds inhabit. While this does not belie the need for conservation efforts here in Alberta, it is important to remember that such efforts may be undermined, if cross-border efforts cannot be achieved.

Migratory birds generally conduct short-distance movements when they are at their breeding or overwintering grounds and use aerial **migration flyways** for long-distance dispersal. These flyways that span the continent, which can converge around large scale ecological barriers such as mountain ranges, lakes, and rivers forming migration bottlenecks. Landscape permeability exists in two dimensions for birds: terrestrially across the landscape and vertically into the airspace. Features facilitating or obstructing their movement on both planes need to be understood to ensure regional landscape connectivity.

Little is known about the Prairie flyway directly over Alberta's prairies and the Rocky Mountain flyway over Alberta's foothills and parklands. Even less is known about potential flight paths across the prairies and mountains connecting to the Pacific Coast and Intermountain flyways in the case of raptors, and to the Pacific and Central flyways in the case of waterfowl. These migratory patterns will be extremely important to understand in terms of flight altitude and predictability of flight paths inter-annually to inform industrial policies such as wind development guidelines.

In this section, species assemblages that have similar habitat associations, movement behaviour, and feeding requirements are discussed separately within three distinct groups of birds: Waterfowl, Grassland Birds, and Raptors.

5.1   Waterfowl

In this context, waterfowl constitute all birds which are strongly associated with water (rivers, lakes, and wetlands) for substantial portions of their habitat. North America's Prairie Pothole Region, found largely in Canada, is recognized as the most important breeding area for continental waterfowl and an important region for many other bird species. North America hosts seven of the nine tribes of the family Anatidae; two species of whistling ducks; numerous species and subspecies of the true geese; three species of swans; 13 species of dabbling ducks (which include most of the abundant and heavily hunted species) and two species of perching ducks; five species of pochards, or diving ducks; two species of stifftail ducks; and more sea duck species (15) than any other continent (NAWMP 2004).

Waterfowl inhabit a wide variety of niches. Swans are mainly aquatic herbivores, foraging shallow freshwater and estuarine habitats as well as flooded agricultural fields. Geese are mainly terrestrial grazers in arctic to midlatitude regions, although some species (e.g., snow geese) grub rhizomes extensively in wetlands and others graze aquatic plants in shallow marine systems (e.g., brant). Many species also exploit farm fields at some point during their annual cycles. Dabbling ducks exhibit the widest array of habitat preferences: from generalists like mallards to specialized filter feeders, to grazers.

Waterfowl populations are strongly affected by rainfall and related environmental variation. During the late 1990s, most species of prairie-breeding ducks responded to a decade of above average rainfall and unprecedented wetland conditions by recovering to near or above Plan goal levels. Some species, however, have persistently remained well below objective levels. Northern pintails did not respond as expected during the recent wet period on the prairies, perhaps because of the variability of wetland conditions within the prairie pothole region and changing agricultural practices.

5.1.1 General Life-Cycle and Habitat Requirements

5.1.1.1 Critical Habitats

The Canadian Prairie Pothole Region (PPR) is considered the most important breeding area for North American waterfowl populations, spanning from Alberta into Saskatchewan, Montana, the Dakotas, Minnesota, and Iowa (NABCIC 2012; PHJV 2014). The Canadian Western Boreal Forest is the second most important breeding area (PHJV 2014). The PPR is aptly named the "duck factory" or "waterfowl nursery". It also provides key stopover sites and essential habitats for migrating waterfowl (e.g. Trumpeter swan; AESRD 2013) and other species assemblages such as shorebirds (e.g. Piping Plover), waterbirds, and landbirds (PHJV 2009; NABCIC 2012).

Of the 60 target landscapes with the highest long-term average waterfowl densities identified by the PHJV (**Figure 4**) in this region, 26 (43%) are in Alberta, 29 (48%) are in Saskatchewan, and five (8%) are in Manitoba (PHJV 2009). The Prairie Habitat Joint Venture defines three groups of birds based on their habitat requirements that are dependent on the Prairie and Parkland landscape. They are:

1) Prairie breeding species that use wetlands or may frequently occupy uplands in moderate to high-density wetland landscapes.

2) Prairie breeding species that are characteristic of moist mixed-grass prairie, mixed-grass prairie, and sagebrush shrublands in lower density wetland landscapes.

3) Waterbird and shorebird species that use wetland habitats in the Prairie Parkland Region during migration.

For some species, it is not only the local habitat variability and quality of the wetlands that is important, but also the spatial distribution of wetlands at larger spatial scales (Naugle et al. 2011). Continentally there is a preference for protecting wetlands that are large and perennially connected. These larger wetlands can support open deep-water habitats with more habitat heterogeneity, which is critical for area-sensitive species (Ma et al. 2010). However, smaller and widely scattered wetlands and wetland complexes, although supporting lower species diversity at a single site (Ma et al. 2010), can be critically important for species that are highly mobile and do not require large wetlands (Haig 1998; Niemuth et al. 2006). The highly mobile northern pintail, for example, selects and uses multiple suitable wetlands over larger spatial scales and is vulnerable to the removal of small wetlands (<0.5ha; Naugle et al. 2011). Therefore, numerous small wetlands may be of equal or greater importance to fewer, larger ones for some species of waterfowl and migratory shorebirds (e.g. Niemuth et al. 2006).

The position of these wetlands in the surrounding landscape can also influence site suitability. Migratory shorebirds, for example, preferentially select seasonal wetlands that are surrounded by permanent and semi-permanent ones (Niemuth 2006). Therefore, wetlands should be acquired not only as core areas with high average waterfowl densities, but also as sites that maintain regional wetland connectivity (Niemuth 2006; Naugle et al. 2011).
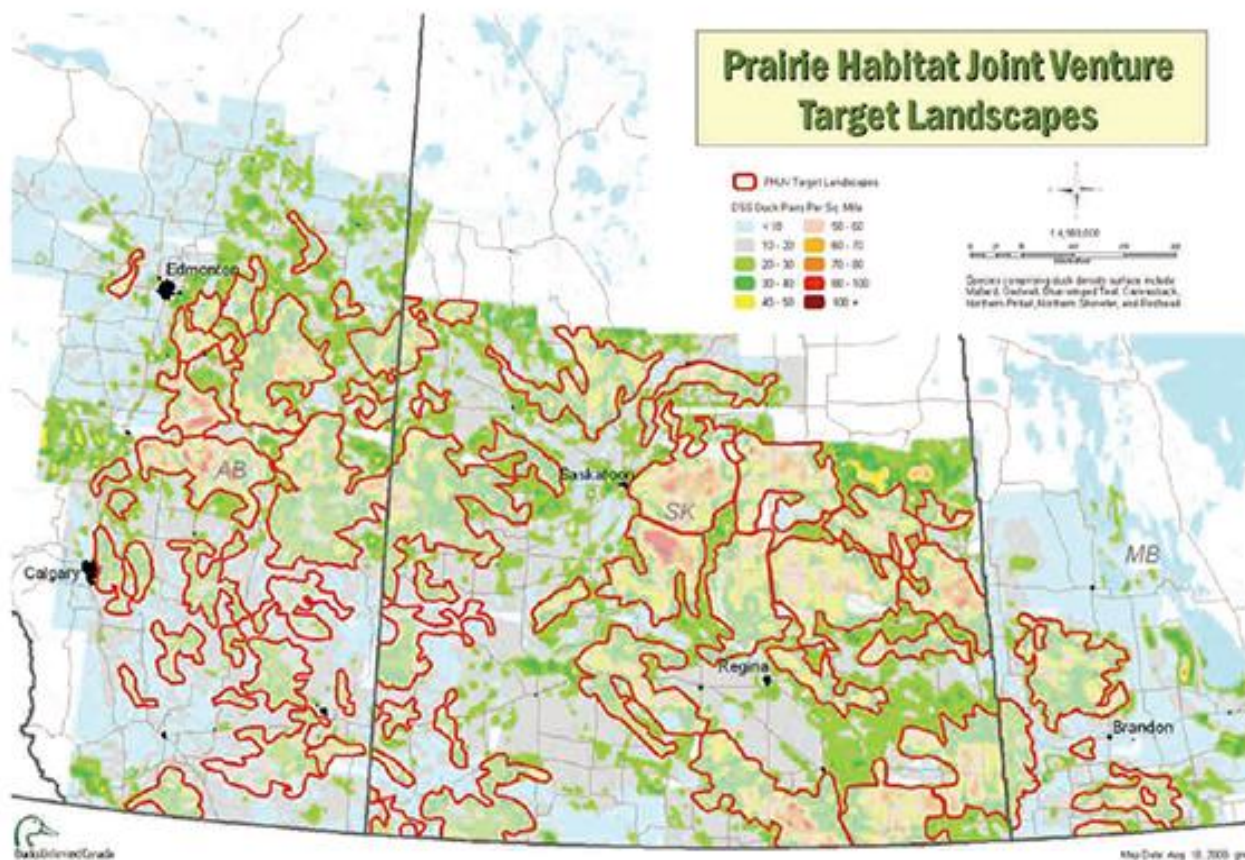
Figure 4: Target landscapes identified by the Prairie Habitat Joint Venture to preserve essential duck breeding habitat.

5.1.1.2 Isolated Habitats

Waterfowl and shorebirds are primarily dependent on the characteristics of individual geographically isolated wetlands and their spatial distribution and, to a lesser degree, on the habitat characteristics of the surrounding landscape (Haig et al. 1998). For example, during spring migration, shorebirds select small, isolated temporary and seasonal stopover sites within agricultural fields at two scales. Locally, they select wetlands that have water present during multiple visits, little emergent vegetation, large perimeters (e.g. greater foraging areas), and less evidence of drainage. Regionally, they select wetlands that have the presence of other wetlands (i.e. permanent and semi-permanent) in the surrounding landscape (Niemuth et al. 2006).

The disjunct nature of these wetlands makes these birds more vulnerable to population decline due to threats at these sites, especially when they have high site fidelity and flock to them in larger numbers (Haig 1998), such as at staging sites during the migration period. Populations reliant on snowmelt and rain have experienced significant population declines (>70%) due to severe fluctuations in water levels (e.g. northern pintail and horned grebe; NABCI 2012; PHJV 2014). Thousands of birds migrating to or through Alberta use these critical migratory stopover or staging sites. It is important to note that the primary stopover region for Alberta's breeding waterfowl falls within midcontinental North America ("stopover country"; DUC), stressing the cruciality of building international conservation capacity.

5.1.2 Movement Patterns

Waterfowl can travel in flocks composed of loose groups associated with different flocking behaviours such as small, compact groups (e.g. teals, northern shovelers) and Vs or wavy lines (e.g. canvasbacks) (EC 2014). Their behaviour also varies during takeoff and landing from water or land.

5.1.2.1 Long-Range Dispersal Movements

Migration flyways are part of a continental habitat network, with migratory movements occurring between breeding and overwintering sites. The Trumpeter swan, for example, migrates in a stepwise manner (Mitchel 1994), primarily using the Pacific and Central flyways (AEP 1997) and relying heavily on its annual stopover sites (LaMontagne et al. 2001) as stepping-stones to facilitate migration.

5.1.2.2 Localized Movements within the Home Range

Localized movement at this scale can be considered part of a smaller regional habitat network. Movements at this scale primarily focus on daily movements between foraging areas and a nesting site within a restricted home range. The home range size is not primarily defined by dispersal ability, but also by the willingness and need to disperse longer distances to forage away from young.

Waterfowl and shorebirds can have site fidelity to wintering and breeding sites, returning annually to their natal or breeding site or selecting new sites by finding the first available and suitable habitat (Haig 1998). Finding alternative suitable sites can be critical to respond to habitat loss or degradation. Exploratory movements to assess nesting territory and foraging quality for subsequent years might directly improve reproductive success (Haig et al.1998).

5.1.3 Movement Facilitators

Birds breeding in Albertan wetlands and/or native grassland habitats are primarily migratory, arriving from their wintering grounds in the USA and Central or South America. Depending on the species assemblage (e.g. Grassland Birds), they select strong predictable migration corridors across the continent between major **breeding** and **wintering grounds**.

These migration flyways can be continental or intercontinental and span hundreds of kilometres over land and/or ocean (**Figure 5**). Birds travelling to Alberta primarily fly through the Pacific and Central migratory flyways. As they approach, they follow major rivers and mountain ranges (NWF 2016). These flyways can have several individual "pathways" or "flight lines" within them (Hoffman et al. 2002).

When individuals migrate together from a single breeding population in Alberta to the same overwintering grounds, their flightpaths become critical to maintain, since there are few or no redundant links (e.g. Webster et al. 2002). This strategy also makes migrants more vulnerable, since their movement network is less resilient overall to change. However, when individuals migrate to Alberta, they arrive at multiple locations through multiple corridors, this means that there are fewer individuals travelling within individual corridors (less ecological flow). These redundant links make the network more resilient overall to link or stopover habitat removal since known alternate routes can be followed in subsequent years (e.g. Webster et al. 2002). Another important factor associated with some of these corridors is movement

Figure 5: North American migratory flyways: 1) Pacific, 2) Central, 3) Mississippi, 4) Atlantic (NWF 2016).

directionality, especially for species that are dependent on unidirectional features like thermal updrafts for flight (e.g. raptors).

During the pre-migratory period, birds build up body fat reserves at their breeding and overwintering grounds. In Alberta, the primary breeding ground for most birds is found on the prairie landscape; however, there are others that stop over en route to their final destination. These "stopover" sites are vital habitats that are critical to survival as they allow fatigued birds to rest, drink, and feed. Migrants typically spend more time at these sites than they do in flight, since few birds conduct non-stop flights (Faaborg et al. 2010). These sites act as stepping

stones along migration flyways, ensuring that migrants have enough energy to continue. Habitat loss at these sites can cause major mortality events (Rosenberg et al. 2016), since even if another suitable site is found, overcrowding at remaining sites can cause a shortage of available resources (Amezaga et al. 2002), resulting in mortality up to 15 times higher than any other time of year (Rosenberg et al. 2016).

Stopover and staging sites are terms that are often used interchangeably; however, for the purposes of this document, they will describe different dispersal strategies. Stopover sites describe locations where migrants that travel shorter distances "hop or skip" from to rest and refuel. Staging sites describe locations that migrants will "jump" over longer distances to reach, these sites attract thousands of birds, have abundant and predicable resources, and enable long stopover durations (Warnock 2010). Due to the continental scale of these movements, Alberta may only house one or a few of these critical sites within its boundaries.

Continentally, there is a critical need to ensure that full life-cycle requirements (CEC 2013; Rosenberg et al. 2016; PIF 2013) are sustained to ensure continued persistence of migratory birds within the grassland and parkland regions. Reduction in habitat quality at continental wintering grounds in the United States and Mexico influences the survival and reproductive ability of birds arriving at their Albertan breeding grounds (PIF 2010). Therefore, to reverse species' decline and ensure persistence and successful arrival of migrants in Alberta, building international conservation capacity between Canada, Mexico, and the United States is vital to manage habitats at overwintering, stopover, and staging sites (PIF 2016; CEC 2003; PIF 2013).

Wetland networks are expected to experience reduced connectivity in the future (e.g. temporary and permanent), since the climate in the prairie pothole regions of not only Alberta, but also the entire Great Plains biome, is expected to become drier. Wetland networks are distributed in various configurations. Clustered wetlands are comprised of one wetland that is a hub and acts as a focal connection point with a high number of connections to other wetlands. Stepping-stone wetlands are a series of wetlands that facilitate movement in a stepwise manner. The loss of both clustered and stepping-stone wetlands greatly affects overall network connectivity by functionally isolating wetlands.

The dispersal ability and scale at which birds select and use wetlands at different scales affects the overall connectivity of the region. Moreover, water availability from year to year changes the use of wetlands and therefore, the configuration of the network and the location of a habitat acting as a hub or a stepping-stone. This greatly complicates conservation efforts that target the preservation of key habitats to retain functional connectivity that are relevant and resilient to fluctuating environmental conditions (McIntyre et al. 2014). A more dynamic approach to identifying essential habitats accounting for not only different life stages, but also variable climatic conditions, will likely be required to ensure continued functional connectivity for these species.

5.1.4 Movement Inhibitors

Flight barriers for different species of birds during migration can depend on the altitude at which they fly. Windfarms have been shown to impact Eider flightpaths, but not by more than ~500m (Masden et al. 2009). Large urban areas are avoided by many species that require large patches of native vegetation, especially those sensitive to noise and light pollution.

Recently, there is increased recognition that airspace is important for avian conservation. This recognition introduces new perspectives to the concepts of permeability and barriers through airspace or "aeroconservation" (Davy et al. 2017). With further research and supporting legislation and policy, this awareness could lead to the protection of critical airspace or *aerial habitats* (Diehl 2013) for birds and migration flyways (Davy et al. 2017).

If airspace is visualized as a continuous surface, as one might visualize a resistance surface, barriers disrupt the continuity of this surface, acting as partial or complete impediments (Davy et al. 2017). Large-scale ecological barriers are typically oceans, mountain ranges, and deserts, which can be complete barriers that force birds to conduct non-stop nocturnal and diurnal migration. Small-scale barriers include anthropogenic infrastructure such as major roads, urban centres, airports, wind farms, and communication towers (Davy et al. 2017).

Birds fly at different altitudes, and airspace from this perspective can be divided into vertical strata, much like oceanic intertidal zones (Adams Pers. Comm. 2017; Davy et al. 2017). Flyways and localized flight paths that intercept these barriers can lead to mortality hotspots. In Canada, bird mortality due to collisions is primarily caused by small-scale barriers – vehicles, houses, and transmission lines. Collision rates with vehicles fluctuate seasonally, when movement activity increases or when inexperienced juveniles begin to fly, resulting in peak collision periods with vehicles during the breeding and fledging periods (Bishop and Brogan 2013). Collisions with wind turbines caused less than 0.1% of avian deaths per year (Erickson et al. 2014).

For many birds, movement is bimodal — they employ flight and terrestrial movements (e.g. grassland passerines), but for others there may be a greater reliance on terrestrial movements (e.g. grouse). Therefore, to demystify movement permeability, future research might benefit from an approach combining terrestrial and aerial landscape permeability. Waterfowl and Shorebirds

Waterfowl include various species of ducks, geese, and swans, many of which are also gamebirds. The Bird Conservation Strategy for the Prairie and Northern Region (2013) identified 29 waterfowl priority species (59% of all waterfowl species) and 25 shorebirds (64% of all shorebird species). These are species of national and continental concern and are considered priority species as they are vulnerable due to their population size (PHJV 2013). These species also overlap with the seven primary waterfowl species identified by the Prairie Habitat Joint Venture (PHJV 2009). General Life-Cycle Habitat Requirements

Waterfowl and shorebirds rely directly on wetlands during breeding, migration, and/or overwintering seasons (McIntyre et al. 2014). They are highly mobile, migrating long distances annually and at different stages of their life-cycle use multiple wetlands at different scales (Haig et al. 1998).

To effectively plan, monitor, and conserve these birds for their full life-cycle, we need to consider multiple spatial and temporal scales during breeding (e.g. local, regional scales) in Alberta, and effectively collaborate with conservation partners to manage habitats during the overwintering (e.g. local, regional scales) and migratory (e.g. continental scale primarily focusing on Albertan staging sites) seasons. Moreover, we need a better understanding of which specific sites are locally, regionally, or continentally significant for certain species or for the species assemblage (NAWMP 2014).

5.2   Grassland Birds

Grassland birds, in this section, include grassland passerines (commonly known as songbirds) and grouse that nest in grasslands. Traditionally, grassland birds include species that use woodland, shrubland, and wetland habitats, such as raptors (e.g. CPPIF 2004). However, for the purposes of this document, they are discussed separately.

Group	Common Name	Latin Name	Provincial Status
Grassland passerine	Baird's sparrow	*Ammodramus bairdii*	*Special Concern*
	Sprague's pipit	*Anthus spragueii*	Sensitive
	Bobolink	*Dolichonyx oryzivorus*	Special Concern
	Grasshopper sparrow	*Ammodramus savannarum pratensis*	Special Concern
Grouse	Greater sage-grouse	*Centrocercus urophasianus*	At Risk
	Sharp-tailed grouse	*Pedioecetes phasianellus*	Sensitive

5.2.1 General Life-Cycle and Habitat Requirements

Grassland passerines are migratory birds that respond to year-to-year prairie dynamics (Faaborg et al. 2010). Unlike species that may respond after longer time periods, grassland passerines are highly mobile foragers without highly specialized habitat requirements and are therefore less restricted in their selection of yearly habitat. This allows them to more closely track changes in land cover and environmental conditions. During their life cycle, they breed in Alberta, migrate to the midcontinental United States, and overwinter primarily in the Chihuahan desert of Northern Mexico and southwestern Texas (80% of passerines; Duarte et al. 2011; CPPIF 2014). Breeding success in Alberta plays a strong role in the maintenance of sustainable populations of these species, placing significance on provincial conservation efforts.

Examples of common grassland passerines include chestnut-collared longspur and McCown's longspur. Several less common species include Baird's sparrow, long-billed curlew, and Sprague's pipit. There is a need for a better understanding of connectivity and habitat requirements during different life stages as their specialization

and dependence on grasslands make them vulnerable to habitat loss at each stage of their life cycle (McCracken 2005).

Grouse, on the other hand, are primarily permanent residents that gather on leks to perform courtship displays during the spring breeding period. They can occupy the same range during the summer and winter periods, or shift their winter range to nearby areas with available resources (Tack et al. 2011).

5.2.1.1 Critical Habitats

During the breeding period, Alberta provides essential habitat for many grassland passerines (Sauer et al. 2014) that are mostly or completely dependent on grasslands and predominantly nest on the ground (McCracken 2005). There is a lack of information on the importance of functional connectivity for passerines at their breeding grounds in Alberta. However, there is an abundance of knowledge describing habitat composition and configuration as important, both of which are components of structural connectivity.

Most passerines are not restricted to broader grassland classification, but are associated with a variety of local grassland habitat characteristics, such as vegetation structure, litter cover, and grassland patch size (Please see CPPIF 2014 for detailed habitat requirements by species; **Figure 6,** CPPIF 2014).
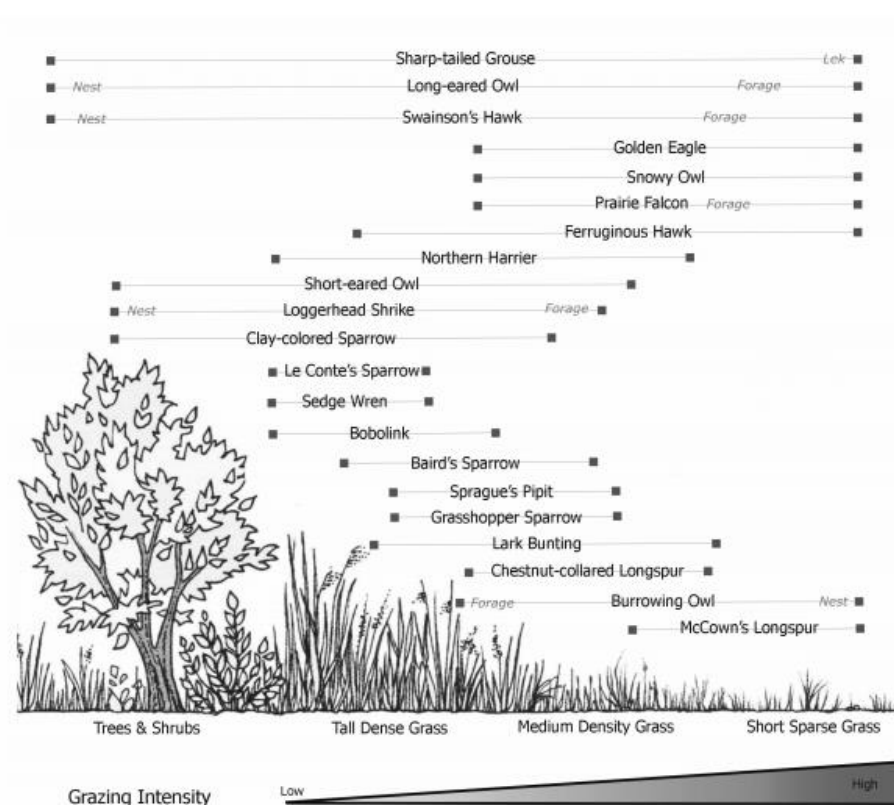
Figure 6: The association between vegetation structure and grazing intensity for priority species in BCR 11, including several grassland passerines, throughout their life cycle (PHJV).

In terms of landscape configuration, many passerines in Alberta are pushed into habitats that are less suitable than large tracts of contiguous grasslands. These habitats include well-managed farmlands and pasturelands or small remnant grassland patches — the suitability of these habitats declines precipitously with increasing intensity of cultivation (Askins et al. 2007; NABCIC). Many passerines are **area-sensitive**, requiring a minimum size of appropriate habitat before they will make use of it (e.g. Sprague's Pipit, Baird's Sparrow, Grasshopper Sparrow, Chestnut-collared Longspur; Davis 2004; Davis et al. 2013). These species tend to select larger patches over smaller ones (Ribic et al. 2009); the larger the patch the more birds it can sustain (Davis 2004; Davis et al. 2013). However, only the largest contiguous patches can support viable populations with diverse grassland bird communities (e.g. ≥100 ha; Vickery et al. 1994; Johnson 2001). Small patches (<10 ha),

especially if they are linear, can be detrimental (McCracken 2005) as linear patches have more edge than interior habitat, which exposes passerines to **edge effects** such as noise pollution, nest predation, and cowbird parasitism (Koper et al. 2009).

Grouse are dependent, at all life stages, on the appropriate canopy cover, height, and density of sagebrush; this association is strongest in winter when sage-grouse forage in large dense stands of sagebrush that remain above snow (Homer et al. 1993, Doherty et al. 2008). They also have high lek site fidelity (CPPIF 2014), although there is evidence that genetic flow between lek sites does occur (Tack et al. 2011).

5.2.1.2 Isolated Habitats

Grassland passerines are highly mobile species; however, during the breeding and overwintering periods they travel more modest distances. Geographically isolated grassland habitats of large size are of great value to grassland passerines. Improving the structural connectivity of these habitats increases their size and therefore, increases passerine abundance; however, further research is required to determine if improving their functional connectivity improves their value.

Dispersed/isolated lek sites minimize the risk of single catastrophic impacts that might otherwise impact the species. However, annual movement is typically short range during the breeding season (and winter movements are typically well below 40 km; Carpenter et al. 2010)

5.2.2 Movement Patterns

Grouse have short, rounded wings with a large amount of flight muscle for strong, fast flight with high-power requirements. This means that they are not capable of sustaining long aerobic flights (Pennycuick et al. 1994) at comparable distances to migratory grassland passerines. As they do not gain elevation readily, fence collisions during flight pose a challenge to connectivity. Grassland passerines, on the other hand, have sharper, pointed wings designed for quick bursts of controlled flight (Scott and McFarland 2010) and can fly much longer distances.

5.2.2.1 Long-Range Dispersal Movements

Most grassland birds in Alberta are migratory, arriving from their wintering grounds to breed in native grassland habitats (CEC 2013). The southeastern portion of Alberta, southern portion of Saskatchewan, and small southwestern portions of Manitoba contain the highest density of breeding species. Movement into these areas from winter ranges through the central portion of the United States (Texas, Colorado, Nebraska, the Dakotas, and Montana; **Figure 7**) is particularly important for maintaining populations in Canada. At the continental scale, functional connectivity and successful migration of passerines from their overwintering to their breeding sites is of importance. Like waterfowl and shorebirds, building international conservation capacity to protect these migratory passerines throughout their full life cycle is vital. For example, deteriorating habitat conditions at their primary overwintering site in the Chihuahuan desert directly affects their persistence in Alberta's prairie and parkland landscapes.

During migration, geographically isolated stopover sites are important for many migratory birds. Little information in known on full life-cycle connectivity and the use of predictable stopover sites in the midcontinental United States for grassland passerines. Problematically, although site-level characteristics undoubtedly play a role in the selection of stopover sites, they are likely to be confounded with broader landscape features. Identifying small, discrete suitable sites within an agricultural matrix is likely an oversimplification for passerines (Ruth et al. 2012), especially since many birds, such as waterfowl, do not stopover together at specific sites, but do so diffusely over the landscape (PHJV 2014). With the advent of new technologies (e.g. geolocators, nametags, stable-isotopes), these gaps in our knowledge are gradually being filled.
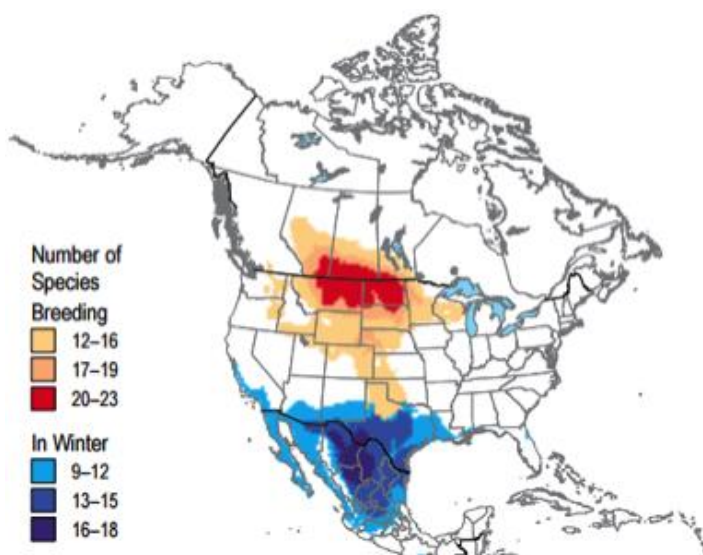
Figure 7: Partners in Flight (2010).

5.2.2.2 Localized Movements within the Home Range

During the breeding season, grassland passerines, such as the Baird's Sparrow, fly short, localized distances between breeding and foraging sites within their home range (Gordon 2000).

Both the greater sage-grouse and the sharp-tailed grouse are permanent residents, unlike the migratory grassland passerines. The former conducts short migrations only during harsh winters (Aldridge 1998). The latter conducts short movements to more wooded habitats (Kobriger 1965 and Gratson 1988 in CPPIF 2014), flocking together with other sharp-tailed grouse in November for the winter (AEP 2009). Both species have very restricted ranges. The sharp-tailed grouse's spring and summer home ranges vary from 13-406 Ha and their winter home ranges vary from 22-752 Ha (Saab and Marks 1992, reviewed in Connelly et al. 1998 in CPPIF 2014). However, despite the size of these areas, most activity occurs within a short distance (5-6.5 km) of their leks (Prose 1987, Giseen and Connelly 1993 in CPPIF 2014), with nesting activity also occurring within this range (Aldridge 1998, 2000, Kobriger 1965, Gratson 1988, Saab and Marks 1992 in CPPIF 2014).

5.2.3 Movement Inhibitors

Most grassland birds are diurnal migrants and, unlike nocturnal migrants, they are not typically subject to high mortality from collisions with tall anthropogenic structures (e.g. sky scrapers, lighthouses) during migration (McCracken et al. 2005). However, passerines and owls are the most common species assemblages that collide with vehicles along roads, with peak collision occurring during fledging and with the risk of collision typically increasing with traffic volume and road speed (Kociolek and Clevenger 2011). Some birds have been observed to adapt their flight behaviour by increasing their flight initiation distance with the speed limit (20-110 km/h) of different sections of roads to minimize collision risk (Legagneux and Ducatez 2013).

5.3   Raptors

In Alberta, raptors associated or dependent on grasslands for one or more stages of their life-cycle include falcons (genus: *Falco*), large hawks (genus: *Buteo*), some woodland hawks (genus: *Accipiter*), eagles (genus: *Haliaeetus* and *Aquila*), and owls.

Group	Common Name	Latin Name	Provincial Status
Falcons	Peregrine falcon	*Falco peregrinus*	At Risk

Hawks	Ferruginous hawk	*Buteo regalis*	At Risk
	Swainson's hawk	*Buteo swainsoni*	Sensitive
	Cooper's hawk	*Accipiter cooperii*	Secure
Owls	Burrowing owl	*Athene cunicularia*	At Risk
	Snowy owl	*Nyctea scandiaca*	Secure
Eagles	Golden eagle	*Aquila chrysaetos*	Sensitive

5.3.1 General Life-Cycle and Habitat Requirements

Raptors in the Albertan prairies are migratory birds, many of which arrive to breed and some of which arrive to overwinter from their northern breeding grounds (e.g. snowy owl; AEP 2014). Like other migratory birds, degradation of their wintering habitats can reduce their survival and dispersal ability during migration, affecting their ability to breed successfully.

5.3.1.1 Critical Habitats

Raptors are predators whose essential habitat is often directly tied to the distribution of their prey and therefore, habitats suitable for their prey. They also require essential habitat features for nesting (e.g. trees, mammal burrows). Raptors can have a range of variability and tolerance to modified prairie landscapes. The Swainson's hawk, for example, prefers grasslands interspersed with agricultural fields over contiguous grasslands (Schmutz and Hungle 1989) and is more abundant in moderately cultivated areas than intact grasslands (Schmutz 1987).

Many raptors breed in the prairies and are reliant on essential habitat features such as riparian areas, valley bottoms, undisturbed grasslands and shrublands, and old fields that are beneficial for nesting, roosting, and feeding. *Buteos* and *Accipiters* additionally benefit from protected wood-lots, hedgerows, and natural forest openings (Demarchi and Bentley 2005). Peregrine falcons, for example, are widespread in Alberta and they can nest on sites such as cut banks of major rivers and streams, stone cliffs, and man-made structures. The plasticity of this species makes it difficult to identify critical habitat. The main populations of raptors, Northern and Southern, are found in urban/industrial areas in the grassland and parkland regions of Edmonton, Calgary, Wabamum Lake, and the Red Deer River valley. Raptors can not only have high site fidelity to these nesting sites (e.g. prairie falcons), but also to their breeding and wintering grounds (e.g. golden eagle; AEP 2014).

Eagles (golden and bald eagles) primarily breed in the northern boreal forest region, but can also breed on cliffs in river valley in the prairie region. They also stopover during migration through the prairies and can, but do not primarily, overwinter in the south of the grassland region (AEP 2014).

5.3.1.2 Isolated Habitats

Some raptors are vulnerable to human disturbance during breeding periods (e.g. golden eagles, ferruginous hawk) and require suitable nesting structures that are more isolated to breed successfully. The ferruginous hawk, for example, relies on remnant trees in the prairie landscape. If disturbed, it can abandon its nest during the incubation period and even if it does not, fewer and smaller young will fledge (AFHRT 2009).

5.3.2 Movement Patterns

Large hawks and eagles have broad wings and long tails that are designed for soaring and gliding. Falcons have long, pointed wings and narrow tails that are designed for flapping. Prairie and peregrine falcons are an exception as they can also soar on updrafts (AEP 2009). These species are often seen circling or hovering over portions of their territory that contain high densities of prey species.

5.3.2.1 Long-Range Dispersal Movements

There are three western North American continental migratory flyways that raptors breeding and overwintering in Alberta use for migration: the Rocky Mountain, Intermountain, and Pacific Coast flyways (**Figure 8**, Hoffman et

al. 2002). Together, they are part of the Trans-American Flyway, which is the most important migratory flyway for raptors in the world (Bildstein). In Alberta, most species of large hawks and eagles migrate during the winter, excepting some falcons and woodland hawks (e.g. Merlins, Goshawks; AEP 2009). However, raptor populations in North America are typically mostly non-migratory (>90%; Goodrich and Smith 2008).

Raptors have behavioural plasticity in their migration patterns; they can either be long or short-distance migrants and are highly opportunistic and flexible with their movement paths. This trait is thought to enhance their ability to adapt to changing conditions during travel.

Figure 8: Western North American migratory flyways. (Hoffman et al. 2002).
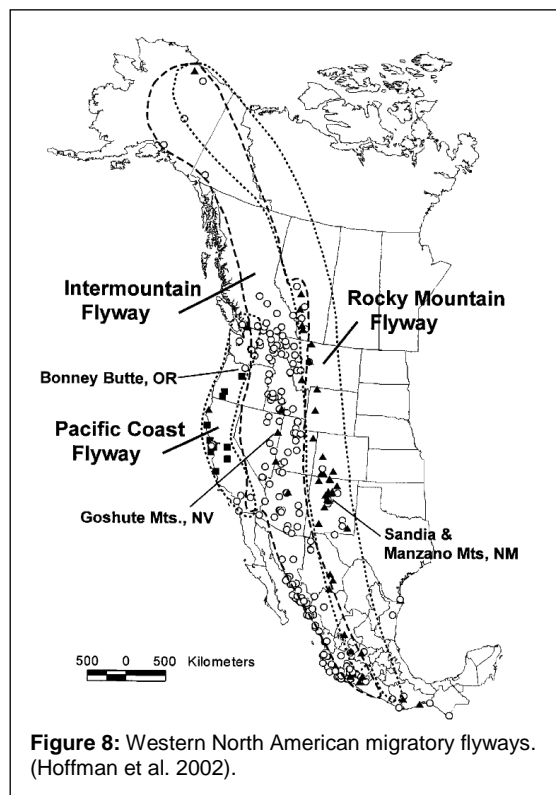
Large hawks and eagles are not designed to flap their wings for prolonged periods and, instead, take advantage of updrafts along mountain ranges, such as the Rocky Mountains, to migrate by soaring (obligate soaring migrant; AEP 2009).

All raptor migrations are influenced by regional geography, especially birds that must soar and cannot flap their wings (Bildstein). Prior to migration, pre-migratory flocking can occur, which is important for inexperienced migrants who learn the flyways by following experienced adults (Bildstein). Migrants initially disperse from their breeding grounds, gradually converging along strong predictable paths southward that improve their flight efficiency. As migrants approach prominent landscapes features, they can become funneled into migration bottlenecks, such as mountain ranges, lakes, rivers, and habitat boundaries.

The Rocky Mountain Flyway, along the eastern slopes of the Albertan Rockies, provides suitable thermals, funnelling migrants into northern Mexico, while the western plains provide suitable habitats for soaring migrants such as Swainson's hawks, prairie falcons, ferruginous hawks, and golden eagles (*Accipiters* and eagles; Goodrich and Smith 2008; Bildstein). The Intermountain Flyway is predominantly used by *Accipiters* and *Buteos*, funneling them into the Great Basin and western North America. The lesser studied Prairie Flyway through Alberta's prairies extending southward, is primarily used by Swainson's Hawks, funneling them across Texas into northeastern Mexico. The Pacific Coast Flyway is primarily used by western *Accipiters* and *Buteos*, funneling them both northward and southward within North America (Hoffman and Smith 2003; Bildstein). Little is known about connection paths to these migratory flyways through Alberta's prairie landscape or usage of the Prairie Flyway directly over it. Future research should track adults and juveniles to discover these migration patterns. Moreover, migratory movements can be changeable, varying between years depending on habitat suitability and weather patterns (Goodrich and Smith 2008).

The protection of airspace within these flyways is extremely important to ensure migratory connectivity and is likely especially important for flyways that are heavily used by soaring migrants that are dependent on suitable thermals to optimize movements.

5.3.2.2 Localized Movements within the Home Range

Raptor movements within a home range are centered around two distinct core areas, one around their nest and a second around their hunting area (Leary et al. 1998), such as grasslands or cultivated fields. Raptor home range sizes can vary by sex, time of year, and availability of prey; generally, raptors with larger body mass have larger home ranges (Peery 2000). For example, male Ferruginous hawks can have mean home ranges of 90 km^2 extending up to 136 km^2 (Leary et al. 1998).

5.3.3 Movement Facilitators

During flight, raptors require thermals or updrafts along habitat features in the prairies such as cliffs and river valleys and good weather windows to facilitate flight (e.g. Pocewicz et al. 2013). Determining the importance and locations of suitable aerial habitats, with favourable updrafts and thermals, may be important to ensure foraging

success for species who hunt by flight (aerial hunter) rather than from perches (Janes 1984, Janes 1985, Widen 1994). The peregrine falcon in Arizona, for example, is an aerial hunter that selects habitat features with high topographic relief, cliffs, and available surface water (Ellis 1982). The Red-tailed hawk, on the other hand, is poorly adapted to aerial hunting and uses perches instead, resorting only to aerial hunting when perches are scarce (Janes 1984). Forested or riparian corridors are another feature that facilitates flight, providing functional connectivity through the agricultural matrix for some, such as the peregrine falcon (e.g. Dzialak et al. 2005).

5.3.4 Movement Inhibitors

Raptors are diurnal migrants. They can suffer fatalities due to storms (e.g. hurricanes) and collisions with wind farms, communication towers, transmission lines, airplanes, and other vehicles (e.g. COSEWIC 2006; Gahbauer 2008). They also tend to get funneled into migration bottlenecks along geographic barriers, such as Alberta's Rocky Mountains. Raptors are particularly vulnerable, even to low levels of mortality threatening their long-term population viability, since they have low population densities and slow reproductive rates (Manville 2009; Zimmering et al. 2013).

In the future, it will be important to conduct collision risk modelling for raptors to determine existing and future risk, especially with the advancing prospects of the wind energy industry. Currently, collisions with wind turbines are not the primary contributor to bird mortalities in Canada. However, with their continuing expansion, there is an opportunity for the management of turbines and wind farms to be informed by the locations of migration flyways and habitats that are important for species dependent on aerial hunting. If wind farms are located around features that naturally bottleneck migrant movements (e.g. mountain ranges) or are in high-risk areas, it may be necessary to shut down operations during peak activity periods of spring and fall migration, since raptors are diurnal migrators. Wind energy guidelines should contain protocols for such extreme situations (e.g. Carrete et al. 2009). Future research is required to conduct a comprehensive analysis in Alberta of the effects of turbine collision, access roads, construction of turbine pads, and power lines over multiple years and seasons, which will help inform future locations of turbines (Zimmering et al. 2013).

HERPTILES

Herpetofauna — subdivided into amphibians and reptiles — are ectotherms incapable of regulating their own body temperature. Ectotherms regulate their temperature through specific behaviour, such as basking in the sun or seeking shade (ACA 2010). The highest diversity for herpetofauna is in the southeastern corner of Alberta. Species in this area have extended into the northernmost limits of their range and physiological tolerance to a cold climate (Russell and Bauer 2000). All herptiles overwinter in hibernacula, burrows, or water bodies to survive freezing temperatures and are inactive during these periods; the winter is considered an inactive season, while the spring, summer and fall are active seasons. During overwintering, early and late seasonal extremes are a source of mortality for all herptiles (e.g. Powell and Russell 1994, 1996b in COSEWIC 2004).

In Alberta, incomplete information on the population structure and distribution of herptiles, and status reports require updates. Much of the information assembled in current literature is from studies in more southern ranges and, in some cases, where studies have been conducted in Alberta, herptiles have been observed to adapt some of their behaviours to northern environments.

5.4   Amphibians

Alberta has 10 amphibious species (AEP 2014), eight of which can be found in the Prairie Region, including two salamanders, three toads, and three frogs. Amphibians are widely affected by the cultivation of native grasslands and the simultaneous drainage of wetland habitats. They are sensitive and often considered indicator or sentinel species for environmental health and change (Russell and Bauer 2000).

Amphibians have three distinct core habitats: wetlands, upland foraging habitats, and overwintering sites. Amphibians require geographically isolated wetlands for breeding. Wetlands that are more hydrologically isolated can be rare and fishless, which is beneficial for reproductive success, since it reduces fish predation of juveniles and eggs. After breeding, adults spend a significant amount of time foraging in upland habitats, wherein functional connectivity and habitat contiguity of upland grasslands at a local scale is important for localized movements within a home range.

Juvenile migration is the main form of population and regional connectivity for amphibians, during which time rain events trigger mass dispersal movements. During this period, if breeding ponds are fragmented by roads or adjacent to roads (e.g. drainage or roadside ditches), road mortality can be especially high. Amphibians are generally slow moving when crossing roads exposing them to road mortality risk. Moreover, although Albertan amphibians have high desiccation tolerance, they are at higher risk of desiccation during movements through less preferable cover types (e.g. paved surface versus moist grassland).

Although it is a reptile, the western painted turtle has similar habitat connectivity requirements as amphibians. Adults engage in annual dispersal from an overwintering site to a wetland where they breed, to an upland foraging habitat, and back to an overwinter site.

The northern leopard frog was once a widespread species, inhabiting western and central Alberta from the Grasslands and Parklands to the Foothills. Its range is now restricted to ranges along several rivers within the Grassland Region, with several remnant populations scattered and isolated from each other by expanses of unsuitable habitats. This relatively quick near-disappearance served as a warning and highlighted the need to conduct long-term monitoring of amphibious and reptilian populations (Holroyd et al. 1987). Functional isolation of wetlands worldwide has reduced amphibian biodiversity (Lehtinen 1999).

Group	Common Name	Latin name	Provincial Status
Salamanders	Long-toed salamander	*Amybstoma macrodactylum*	Special Concern
	Tiger salamanders	*Ambystoma tigrinum*	Secure
Toads	Great Plains	*Bufo cognatus*	May be At Risk
	Canadian toad	*Bufo hemiophry*	May be At Risk
	Plains spadefoot toad	*Spea bombifrons*	May be At Risk
Frogs	Boreal chorus frog	*Pseduacris maculate*	Secure
	Northern leopard frog	*Rana pipiens*	Threatened

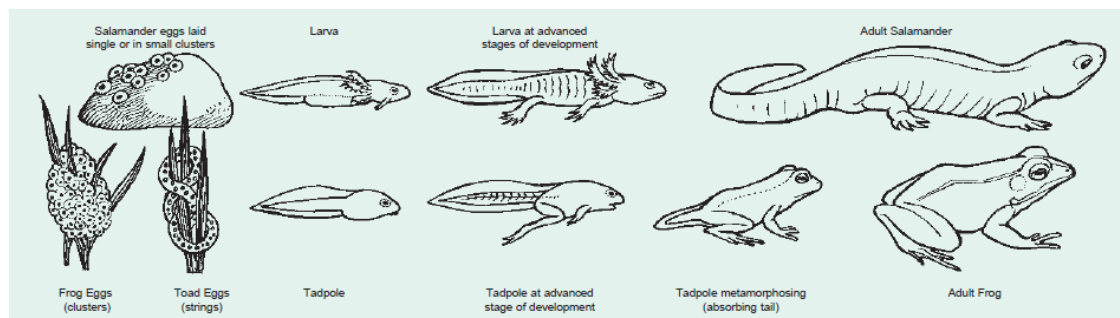### 5.4.1 General Life-Cycle Habitat Requirements

Figure 9: Amphibian life cycles (ACA 2010).

Amphibians require wetlands and water bodies at all stages of their life-cycle (**Figure 9**). Wetlands provide amphibians with important breeding and overwintering habitat, while the surrounding grasslands provide foraging and overwintering habitat, depending on the species. At all stages of their life cycle, they have been seen to select wetlands surrounded by native grasslands over farmlands (Balas et al. 2002). Dispersal occurs during the spring, from their overwintering site to their breeding site, and in the fall from their foraging site to their overwintering site.

5.4.1.1 Critical Habitats

Amphibians require three distinct core habitats – wetlands for breeding; moist upland habitat (e.g. grasslands, meadows, pastures, scrublands) for foraging; and suitable overwintering sites – and some are reliant on episodic rain events for reproduction (e.g. spadefoot toads). During the breeding season for most amphibians at the home range scale, wetland connectivity is important for dispersal from the overwintering site to the breeding site. At a local scale, warm shallow water and aquatic vegetation is important when selecting a breeding site (e.g. emergent vegetation) for cover, food, and oviposition. To maintain wetland connectivity, the surrounding upland habitat should be conserved, since conversion of these areas significantly affects dispersal ability, potentially leading to genetic isolation and local extinction (Gustafson and Newman 2016). Many amphibians have localized populations in Alberta that occupy pockets of suitable habitats. The Great Plains toad, for example, has three isolated populations in Alberta that are separated from each other by expanses of cultivated land (12-70 km apart, **Figure 10**) that make these populations vulnerable to local extirpation, with no potential rescue effect from neighbouring populations (AEP 2015). This situation is not unique to the Great Plains toad and is shared by others such as the northern leopard frog (AEP 2012) and the long-toed salamander (AEP 2016). Other species are more widespread but are experiencing declines in the Parkland and Grassland regions (e.g. Canadian toad; Browne 2009).
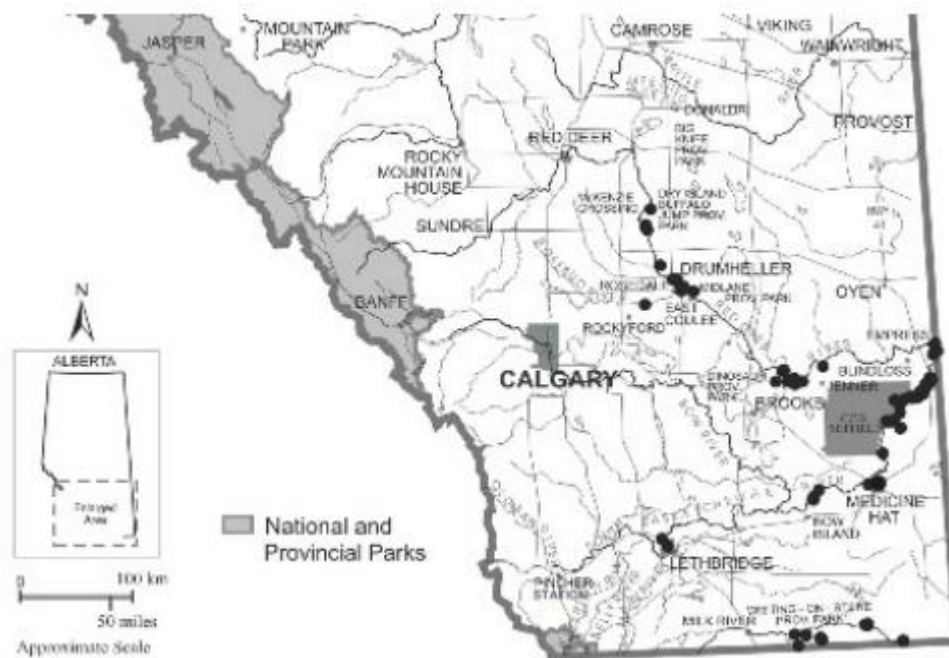
Figure 10: Remaining populations of the Great Plains toad.

During overwintering, an inactive season, amphibians ensure they do not freeze by occupying essential habitats that allow them to remain below the frost line depth (AEP 2016). For frogs, well-oxygenated deep-water wetlands are important (AEP 2012); for toads, suitable soil for burrowing is important (Environment Canada 2013); for salamanders, rodent burrows are important (AEP 2016).

5.4.1.2   Isolated Habitats

Geographically or structurally isolated wetlands (GIW) are part of increasingly large ecological units: wetland complexes, drainages, and watersheds. Although many wetlands, at the surface, appear to be structurally isolated within the agricultural matrix, with no persistent hydrological connections, wetlands are interconnected by subsurface connections within drainages and watersheds, and the water quality and vegetation within them are influenced by the habitat quality and use of the surrounding landscape (Cohen et al. 2015). Therefore, these wetlands are functionally connected by the exchange of ecological flow, even if they are not connected by overland species dispersal.

The limited dispersal accessibility and weaker hydrological connections with downstream waters of some wetlands is what enhances and enables some wetland functions. Many species rely on these wetlands, which may be geographically isolated, but not necessarily functionally isolated during different seasons or life stages.

During the egg laying and larval stages, amphibians can benefit from rare, fishless lakes that are more hydrologically isolated from other basins, have fewer surface connections, and/or are shallow (Herwig et al. 2010). The Tiger salamander, the Northern leopard frog, and the Wood frog are all species whose breeding success in shallow lakes is lowered by increased fish abundance (Herwig et al. 2013).

5.4.2 Movement Patterns

Grassland frogs do not slither between grasses like snakes or push their way through them like turtles, they jump over the tops of grasses using powerful, high-arched leaps (e.g. chorus frog, leopard frog; Norman 1996). Large magnitude migration events of toads and salamanders lead to large mortality events at key road crossings in landscapes where movements are highly constrained or funneled into particularly high-traffic areas.

5.4.2.1 Permeability of the Matrix

For amphibians, the grassland region and cultivated land, forests, and urban/rural areas in other regions are often considered part of the matrix (e.g. Cosentino et al. 2011), while wetlands are considered discrete patches

(e.g. Decout et al. 2012). However, depending on precipitation, the matrix can become habitat as some amphibians can be found breeding in ditches and cultivated fields (Lauzon 1999; AEP 2012; AEP 2015). Urban land cover, generally, provides the highest landscape resistance for amphibians, since paved surfaces pose high desiccation and mortality risk. Softening or restoring the matrix to natural habitats around geographically isolated wetlands at a regional scale can help reduce fragmentation and isolation effects by restoring connections to other wetlands for amphibians (Donald and Evans 2006).

5.4.2.2 Long-Range Dispersal Movements

For amphibians, juvenile dispersal is primarily responsible for maintaining population connectivity (Cushman 2006), since juveniles primarily disperse unidirectionally over long distances compared to the annual dispersal movements of breeding adults (Semlitsch and Bodie 2003). Many amphibians in Alberta have moderate dispersal ability (Shank 2014) and mass dispersal movements occur during periods of high precipitation or warm weather (Andrews et al. 2008). The adult Great Plains toad, for example, can travel between 1000-1600 m (Jeremey et al. 2010).

Generally, Albertan amphibians have high desiccation tolerance (AEP 2012), which is an advantage as desiccation increases during dispersal and the desiccation risk of different land covers can play a role in the selection of movement paths (Andrews et al. 2008). Generally, amphibians select native grasslands over agricultural areas for travel at all life stages (e.g. Balas et al. 2002). Conversely, salamanders can follow moisture gradients, moving more easily through forested areas for dispersal (AEP 2016; Ngo et al. 2009; Goldberg and Waits 2010).

Features flooded anthropogenically or during rain events such as grassy pools, slow-moving streams and rivers, riparian corridors, moist habitats, and flooded fields, ditches, dug outs, and flood plains can facilitate movements of frogs. In some cases, drainage ditches containing water can facilitate amphibian movement between isolated habitats (e.g. Mazerolle 2004). Wetlands and surrounding upland habitats can act as stepping-stones (e.g. Watts et al. 2015) to facilitate movement within a network of wetland habitats (Semlitsch and Bodie 2003). Therefore, to maintain functional connectivity and restore metapopulation stability, identification of core habitats is of primary importance for local populations prior to conserving upland habitats surrounding these areas at a regional scale (Semlitsch and Bodie 2003).

5.4.2.3 Localized Movements within the Home Range

As a larva or tadpole, an amphibian is purely aquatic and depends on the structural hydrological connectivity of wetlands, water bodies, and streams. In the prairie pothole region, wetland complex connectivity is temporal. Surface connections are intermittent, since they are often impermanent, temporally discontinuous, or sporadic. These intermittent connections naturally depend on precipitation and snowmelt in Alberta to connect temporally isolated populations during aquatic life stages and to facilitate dispersal during more mobile and terrestrial life stages. They are thought to be particularly important for amphibians that have floating reproductive bodies (e.g. eggs; Leibowitz and Vlining 20002). In more mobile life stages, the higher the species' mobility, the more it is affected by habitat loss and fragmentation (Cushman 2006).

After breeding, adult amphibians require upland habitats that can range from 159-290 m for foraging. Therefore, these upland habitats require meaningful buffers at a local scale that adequately reflect the range of localized movements during the foraging season (Semlitsch and Bodie 2003).

5.4.3 Movement Inhibitors

Climate models forecast warmer and drier conditions, in addition to existing habitat fragmentation and extensive wetland loss. Amphibians will experience great difficulty responding to these changes. They are expected to be more vulnerable, mainly due to the numerous anthropogenic dispersal barriers surrounding their current ranges (e.g. roads; Shank 2014).

During road crossings, they are highly vulnerable, as they cross slowly and experience the highest mortality rates when these roads also fragment wetland structural connectivity or when they are breeding in roadside

habitats. Increased collision rates can also occur during periods of increased movement such as increased precipitation and warm temperatures (Andrews et al. 2008).

5.5   Reptiles

The Grasslands Natural Region houses the greatest diversity of reptiles in Alberta. They are at the northernmost limit of their North American distribution and are primarily live-bearing. Live-bearing females can extend their distribution further north by actively basking and finding warm shelters (ACA 2010), compared to egg-laying females that are restricted by temperatures suitable for incubation (Burger 1991).

There are seven species of snakes, one lizard, and one turtle in Alberta. The most significant threat to these reptiles is the conversion of native habitats into industrial infrastructure and roads (MULTISAR 2015).

Most reptiles in the prairies are at the northernmost tip of their North American distribution, which can extend all the way to northern Mexico. It may be unreasonable, in some cases, to expect a species at the northern fringe of its range to become common or widespread across Alberta. Reptiles in Alberta are mostly snakes (e.g. prairie rattlesnake, plains garter snake, bullsnake, western hog-nosed snake), one species of lizard (short-horned lizard) and a turtle (western painted turtle). They are all ectotherms, they cannot regulate their own body temperatures. To regulate their body temperatures, they are dependent on habitats within suitable temperature ranges and adaptive behaviours (e.g. basking, taking shelter in the shade). Most species disperse twice a year, emerging in the spring from their overwintering sites, migrating to their summer foraging grounds, and returning to their overwintering sites. The short-horned lizard and the western hog-nosed snake are exceptions as they remain on their summering range year-round. Most species must create critical sites called hibernacula to overwinter, requiring existing rodent burrows and loose sandy soils, since only the short-horned lizard and the western hog-nosed snake have digging abilities. The western painted turtle, on the other hand, is a semi-aquatic species that requires water bodies that do not freeze to the bottom to overwinter.

The populations of many reptiles of concern tend to be highly localized and geographically isolated. Their habitat requirements necessitate suitable temperature ranges for breeding and overwintering in a cold climate and suitable foraging habitats during the summer. Many subpopulations for species of concern are isolated at distances that suggest that no recolonization or rescue effects are possible should local extirpation occur; however, it is possible that infrequent nomadic or long-distance migratory movements, exhibited by some, may contribute towards gene flow between existing populations. Some functionally and geographically isolated habitats may be particularly significant for a species because they are large and contiguous, have high-quality habitat, and/or contain a large potentially self-sustaining subpopulation that represents a significant proportion of the provincial population. Although in the case of rare species, much smaller habitats, within 500 m of a known occurrence for example, can be considered critical habitats.

Snakes are more mobile than the other reptile groups. The prairie rattlesnake, for example, is a good disperser, migrating long distances so that breeding sites that are 30 km apart can be considered functionally connected. Moreover, it uses grassland and riparian corridors for dispersal and has strong inter-annual fidelity. The western painted turtle, which inhabits water bodies (e.g. wetlands, slow moving streams) in southeastern Alberta, can be considered connected to existing subpopulations through rivers. Connectivity planning for the western painted turtle should occur simultaneously with amphibians, given their habitat requirement and movement similarities. In addition, much like amphibians, a warming climate, in which more frequent and severe droughts take place, can put stress on western painted turtle populations and restrict their range, forcing individuals whose ponds have dried out to rely on landscape connectivity to find another. Conversely, snakes and lizards are expected to have their ranges expand northward. It will be important to anticipate range shifts (expansion and contraction) of suitable habitats and to identify potential barriers based on these shifts. Based on existing knowledge of their movement capabilities, it is reasonable to assume that these barriers could have a significantly detrimental effect on reptile populations, by reducing their ability to respond to changes in existing habitat quality.

Fragmentation of existing habitats by roads (paved and non-paved) combined with the slow-moving abilities of reptiles makes these species especially vulnerable to road mortality during dispersal, even more so if they disperse longer distances. Species that are especially vulnerable are those that bask on roads and/or do not flee from vehicles, instead exhibiting disadvantageous defensive responses (e.g. prairie rattlesnake's coiling or short-horned lizard's remaining motionless). For species that bask on roads, roads are not only barriers, but also ecological traps. Mitigative measures such as warning signs (especially during peak activity periods, e.g. primarily diurnal activity, dispersal periods), reduced road speeds, culverts (in the case of turtles), and perhaps directive closed fencing may be required. Other features in the landscape that can present a barrier to connectivity include long dispersal distances, high-traffic roads, intensively cultivated areas, densely urbanized

areas, and large rivers (for species without swimming abilities). Invasive species may also impede reptile movements by changing vegetation structure and composition.

It is important to note that regional connectivity is most important twice annually for dispersal to and from overwintering sites during the spring and fall. For some species, especially those that have high fidelity to specific corridors, it is essential to conserve features such as grassland or riparian corridors. When considering connectivity at a local scale during the summer, species move between two core areas of activity from a den or a nesting site to their foraging habitat. Ensuring habitat contiguity with limited fragmentation on their summer range can help ensure safe and successful movements during this period. In cases where roads or trails are already within these areas, more active measures, such as limiting seasonal activities or realigning a road or trail, could be considered for species of concern.

Group	Common Name	Latin Name	Provincial Status
Lizard	Short-horned lizard	*Phyrnosoma hernandesi*	Endangered
Turtle	Western painted turtle	*Chrysemys picta bellii*	Sensitive
Snakes	Bullsnake	*Pituophis catenifer*	Data deficient
	Prairie rattlesnake	*Crotalus viridus*	May Be At Risk
	Plains garter snake	*Thamnophis radix*	Sensitive
	Western hog-nosed snake	*Heterodon nasicus nasicus*	May Be At Risk
	Eastern yellow-bellied racer	*Coluber constrictor flaviventris*	Threatened

5.5.1 General Life-Cycle and Habitat Requirements

During the spring, snakes emerge from their hibernacula at their overwintering sites and migrate to their summer foraging grounds, where they move short distances between a den site and their foraging grounds. In the fall, they return to their overwintering sites. The short-horned lizard and the hog-nosed snake do not migrate annually, they typically remain at their summer foraging grounds year-round to overwinter, breed, and forage (**Figure 11**).
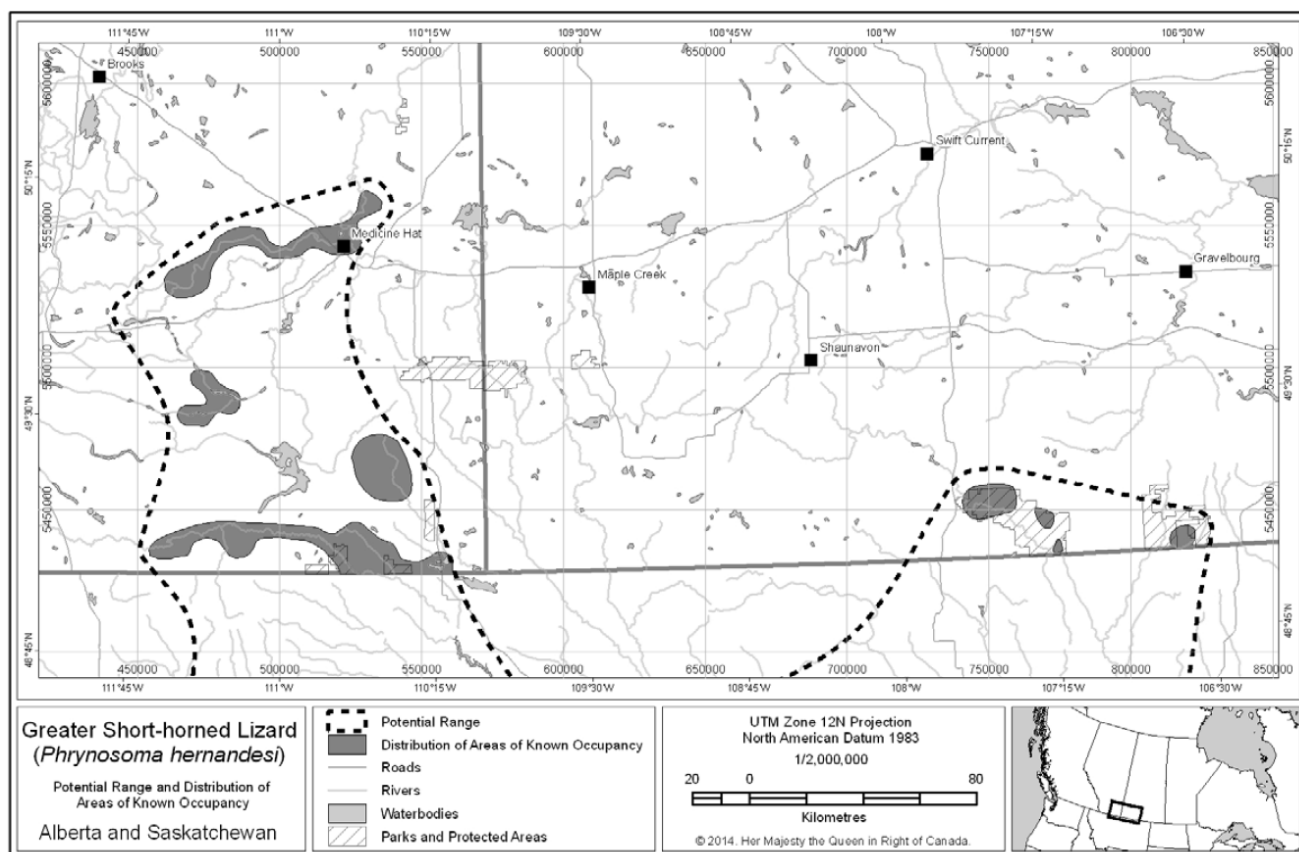
Figure 11: The potential range and distribution of areas of known occupancy of the Greater Short-horned lizard in Canada.

5.5.1.1 Critical Habitats

Hibernacula are important localized sites and critical habitat for snake populations (Holroyd et al. 1987). Reptiles that use hibernacula require conditions where they do not freeze (Russell and Bauer 2000; e.g. Shewchuk 1997; COSEWIC 2004) and there is adequate snow cover for insulation during overwintering (Powell and Russell 1994, 1996). To create hibernacula and dens, snakes typically require sandy substrates or loose soil and rodent burrows. These sites are used for overwintering, refugia (e.g. from heat), and nesting. They can also be communally shared between species, in some cases with hundreds of snakes (COSEWIC 2002), making these locations highly vulnerable. For Prairie Rattlesnakes, bullsnakes, and garter snakes, communal denning is common (Cottonwood Consultants 1987), but for the hog-nosed snake it is rare (COSEWIC 1998). Short-horned lizards also rely on loose soils for burrowing hibernacula (MULTISAR 2015; Russell and Bauer 2000) for overwintering (Powell and Russell 1994, 1996b; James 1997 in COSEWIC 2004) and during the active season for insulation at night (L. Powell pers. comm. 2012 in MULTISAR 2015).

Reptilian distribution covers a wide range of habitats but is limited by suitable temperatures and the extent of suitable foraging and denning habitats. For example, short-horned lizards prefer sparsely vegetated slopes along eroded coulees, canyons, and ravines (MULTISAR 2015); hog-nosed snakes prefer sandy locations (COSEWIC 1998); bullsnakes prefer drier grassland or sagebrush habitats (COSEWIC 2002); and western painted turtles prefer ponds, marshes, ditches, and calm streams (Russell and Bauer 2000).

Habitats suitable for overwintering, breeding, and foraging are essential. Connectivity between these habitats through different seasons is also important for many reptiles. Snakes that become isolated at their summer ranges can die from cold during the winter if they do not find or create another hibernaculum, and snakes isolated at their overwintering range can die of starvation, if they lack foraging habitats (COSEWIC 2002).

Moreover, ensuring connectivity not only through biological seasons, but also through year-to-year environmental fluctuations can be critical. The western painted turtle, for example, is present in few wetlands and lakes in southeastern Alberta, with fewer than 100 individuals in geographically isolated locations. Their existing

subpopulations appear to be connected through rivers in watersheds to their source populations in Montana (COSEWIC 2006). However, during a drought, turtles whose ponds dry out can be forced to find another site, during which time connectivity between suitable water bodies becomes critical (e.g. Bowne et al. 2006).

5.5.1.2   Isolated Habitats

Many Albertan reptiles exist in highly localized and geographically-isolated populations that are at the northernmost tip of their North American distribution (e.g. short-horned lizard; Environment Canada 2015). Although habitats supporting subpopulations can be widely scattered and highly localized, they can be significant for species persistence. The short-horned lizard, for example, has isolated subpopulations within four disjunct areas that are severely fragmented by roads, cultivation, and irrigation in southeastern Alberta. They also have an extremely low probability of recolonization, since the lizard is a poor disperser and the closest subpopulations are within a minimum of 15-20 km. However, even though these sites are functionally and geographically isolated, they can still be of value.

In some cases, isolated patches can become significant when the habitat is high-quality, the patch size is large and/or it contains a large subpopulation. For the short-horned lizard, there is a large remaining contiguous isolated habitat (Manyberries, housing the largest remaining subpopulation in the province — 1/3 of the entire population. The habitat itself is large with high quality and diverse habitat, while other remaining suitable habitats in Alberta are linear and exposed to edge effects (ASRD 2004; Environment Canada 2015). Moreover, due to the rare and localized occurrence of this lizard, critical habitats, even if geographically and functionally isolated, can be defined at a finer scale, as habitat within 500 m of a known occurrence can be considered critical habitat (Environment Canada 2015).

For others, Albertan populations may be isolated remnants of previously continuous populations. The northern population of the hog-nosed snake, for example, is centered along the South Saskatchewan River, while the southern population is in the Milk River Canyon, Wild Horse, and Manyberries region, which is likely contiguous with a population in Montana (Pendlebury 1976). Natural or anthropogenic features within contiguous grasslands can also facilitate predator movement, leading to declines in reptilian populations. Snakes, for example, are subject to predation by mammalian carnivores (e.g. skunks, coyotes, badgers, red foxes, weasels; Shewchuk 1997), raptors (e.g. hawks, golden eagles, red-tailed hawk), and owls (e.g. great horned owls; COSEWIC 1998, 2002, 2004).

5.5.2   Movement Patterns

The hog-nosed snake, bullsnake, prairie rattlesnake, and the short-horned lizard are all terrestrial species, although they have been known to cross rivers and streams during movement. Garter snakes can be aquatic or semi-aquatic, and the western painted turtle is semi-aquatic (Russell and Bauer 2000). They are also primarily diurnal, but the prairie rattlesnake, for example, has been observed travelling at night (COSEWIC 2002). Moreover, reptiles are typically only active during breeding and foraging seasons.

Due to their generally moderate, and in some cases poor (e.g. short-horned lizard), dispersal abilities and susceptibility to anthropogenic barriers, reptiles are expected to have a very limited ability to shift ranges in response to climate change (Shank 2014), although the predicted warmer and drier climate scenarios favours their survival.

5.5.2.1 Long-Range Dispersal Movements

To maintain seasonal and long-term population connectivity of subpopulations, landscape connectivity is likely important during dispersal when most snakes in Alberta migrate twice a year. The prairie rattlesnake, for example, has a bimodal dispersal strategy, wherein, regardless of age or sex, individuals can be short (e.g. <2 km) or long-distance migrants (e.g. 2-12 km; Jørgensen 2009; Gardiner et al. 2013; Gardiner 2012 in COSEWIC 2015). Short-distance migrants typically move through river valley corridors at low elevations. Long-distance migrants move through prairie upland corridors, dens within 30 km have the potential for breeding (Jørgensen 2009). Reptiles also have extremely high fidelity to seasonal migration routes and hibernacula, creating connections between subpopulations. Albertan populations are likely not severely fragmented at broad scales, because dens are likely not beyond the species dispersal abilities and are connected by a riparian network. These long-distance migrations make reptiles vulnerable to increased habitat fragmentation and put them at risk

of mortality. Additionally, at a local scale, populations may also be separated by strong dispersal barriers (COSEWIC 2015) such as major roads or urban residential development.

The western painted turtle, like amphibians, relies on suitable upland habitats to act as terrestrial corridors to provide connectivity during dispersal between geographically isolated core wetlands that act as overwintering and breeding sites within its home range (Gibbons 2003). Individuals to the north of the Montana-Alberta border (e.g. Lethbridge and Edmonton) are present in highly localized and isolated areas and are considered to be escaped or released pets.

5.5.2.2 Localized Movements within the Home Range

Outside of dispersal seasons, snakes are typically seasonally present on their summer range, travelling between two core areas, their den site and their foraging habitat. Bullsnakes, for example, have den sites that are adjacent to their foraging grasslands (Cottonwood Consultants 1987). The plains hog-nosed snake; however, is non-migratory, remaining on its summer range year-round (Wright 1998; Didiuk unpub. Data in COSEWIC 1998) and travelling up to 200 m (Platt 1969). Unlike other snakes, it can dig its own hibernacula with its upturned "hog-like" snout for overwintering (COSEWIC 1998). However, occasionally individuals can become nomadic, travelling up to 250 m per day for two consecutive days (Platt 1969).

Short-horned lizards are small and relatively immobile, travelling a maximum of 1 km (COSEWIC 2004). They occupy a small home range (4.4-2,400 m^2; Powell and Russell 1993b, 1994 in COSEWIC 2004) within which they occasionally move several hundred metres between centres of activity (J. James pers. Comm. 2012, K. fink unpub. Data in Sar 2015). They use roads developed by oil and gas industries (James 2002 in COSEWIC 2004) and tracks left by vehicles through grassy areas as movement corridors, which can lead to road mortality (Powell and Russell 1993a in COSEWIC 2004). Other areas facilitating movement are those with reduced vegetation cover due to livestock grazing (Newbold and MacMahon 2008 in MULTISAR 2015).

5.5.3 Movement Barriers

Invasive species can change the structure and composition of the plant community (Newbold 2005) and may impede reptile movements (e.g. short-horned lizard MULTISAR 2015). Short-horned lizards, for example, avoid dense crops (e.g. alfalfa) or recently cultivated fields with little cover (e.g. short-horned lizard MULTISAR 2015).

Roads with high-traffic volume lead to vehicular mortality for slow-moving reptiles (Cushman 2006). Many reptiles are either hit while crossing or hit while basking. Roads that attract reptile basking behaviours act as ecological traps (Semslitch and Bodie 2003). Finding road mortality hotspots and crossings points within their home range or within migratory corridors is a priority as roads can be and are a major source of mortality for some species. Other species may avoid roads altogether, changing direction as soon as the road is encountered (e.g. eastern garter snakes; Richard et al. 2004; eastern hog-nosed snake; Seburn 2008). There is currently a lack of evidence to confirm if existing barriers are contributing to the genetic structure of reptiles in Canada (e.g. Weyer et al. 2014). Other features that are physical barriers to movement for snakes include long dispersal distances, high-traffic roads, intensively cultivated areas, and densely urbanized areas (COSEWIC 2015).

Rivers are not barriers for many snakes. The prairie rattlesnake and hog-nosed snakes, for example, have been observed, although rarely, crossing the South Saskatchewan and Red Deer Rivers. The SSR, therefore, does not likely do not contribute to strong population isolation for prairie rattlesnakes and hog-nosed snakes (Jørgensen 2009; Andrus 2010; Didiuk pers. comm. 2014 in COSEWIC 2015; S. Brechtel, pers. comm. In COSEWIC 1998). For lizards, however, large rivers may be complete barriers, as they cannot swim (COSEWIC 2004).

MAMMALS

5.6   Large Mammals

Large mammals typically range broadly across the landscape, seeking out natural land cover but willing to cross more disturbed and fragmented lands during daily and annual movement. While bears hibernate during the winter months, many other species are active throughout the year, roaming extensively seeking areas free from snow for forage.

Interactions with humans pose a chief source of mortality, especially for carnivores such as cougars, foxes and wolves. Predation on urban dogs and cats is a growing concern for pet owners, and animal control activities in municipalities and urban areas are frequent occurrences.

The growing recognition of the need to mitigate the fragmenting effect of the road network on large mammal movements has seen increased construction of wildlife overpasses, culverts and other crossing structures, chiefly restricted to National Parks and some urban municipalities. Care must be taken in the planning of these structures to ensure they do not funnel wildlife movement into areas of human use or act as "Ecological Sinks". Connectivity planning must reduce access into human dominated areas, where mortality is high, and instead maintain connections between core areas of native vegetation and low human impact. In areas dominated by cultivation and grazing, fencing strategies should ensure that strong connections between more natural cover are maintained.

Historically, there has been a greater diversity of large mammals on the grassland landscape. The Grizzly bear (*Ursus arctos*; Prairie population), Plains bison (*Bison bison bison*), and Great Plains wolf (*Canis lupus nubilus*) have all since been extirpated (AEP 1997). However, species that co-evolved with them over centuries are still present. Some of these mammals were keystone species or ecological engineers (e.g. the Great Plains wolf suppressed the abundance of coyotes, reducing predation on the swift fox) exerting top-down effects on other species through direct predation and indirectly through changes in the local community of species. Some species played an integral role in the natural disturbance regime (e.g. Plains bison herds), exerting varying intensities of grazing pressure on the landscape and changing vegetation composition and structure. The species discussed in this section are large to medium-bodied mammals and include a variety of ungulates, felids, and canids.

In recent years, cougar (Puma concolor) observations have increased in Midwest North America, with breeding populations re-establishing in several regions east of their contemporary range. The Cypress Hills Uplands, located in southwest Saskatchewan and southeast Alberta, was recently re-colonized by cougars and now supports the easternmost confirmed breeding population of cougars in Canada. Several factors contribute to this cougar-range expansion; however, it is dispersal that provides the mechanism for re-colonization of historic range (Morrison 2015). Populations in and around Calgary and Canmore have become increasingly apparent and human-cougar interactions are increasingly common.

Reintroductions of wolf (*Canis lupus nubilus*) and swift fox (*Vulpes velox*) populations have not seen great success, due to mortality events from human-interactions (in the case of the wolf), and limited suitable habitat coupled with strong impacts from intervening land uses (particularly for the swift fox, **Figure 12**).

Generally, when considering multispecies conservation networks, large wide-ranging mammals are not good umbrella species for predicting the connectivity of smaller mammals (Minor and Lookingbill 2010; Beier et al. 2009). Large mammals view landscape fragmentation and interact with the landscape at different spatial scales than smaller mammals. Smaller mammals often require more strategic linkages (Minor and Lookingbill 2010), experience more isolation, and are influenced by local scale habitat features, especially if they are specialized predators, due to their poorer dispersal abilities (Gehring and Swihart 2002).

Larger mammals require more protected areas and are influenced by landscape scale habitat features due to their higher dispersal abilities (Gehring and Swihart 2002; Minor and Lookingbill 2010). Therefore, to ensure long-term biodiversity and functional landscapes, strategic linkages should be considered at multiple spatial scales for different taxonomic groups and different target species (Minor and Lookingbill 2010).

Group	Common Name	Latin Name	Provincial Status
Ungulates	Pronghorn	*Antilocapra americana*	Sensitive

	Mule deer	*Odocoileus hemionus*	Secure
	White-tailed deer	*Odocoileus virginianus*	Secure
	Elk	*Cervus elaphus*	Secure
	Moose	Alces alces	Secure
	Bighorn sheep	*Ovis canadensis*	Secure
Canids	Swift fox	*Vulpes velox*	Endangered
	Coyote	*Canis latrans*	Secure
	Grey wolf	*Canis lupus*	Secure
	Red fox	*Vulpes vulpes*	Secure
Felids	Bobcat	*Lynx rufus*	Sensitive
	Cougar	*Puma concolor*	Secure
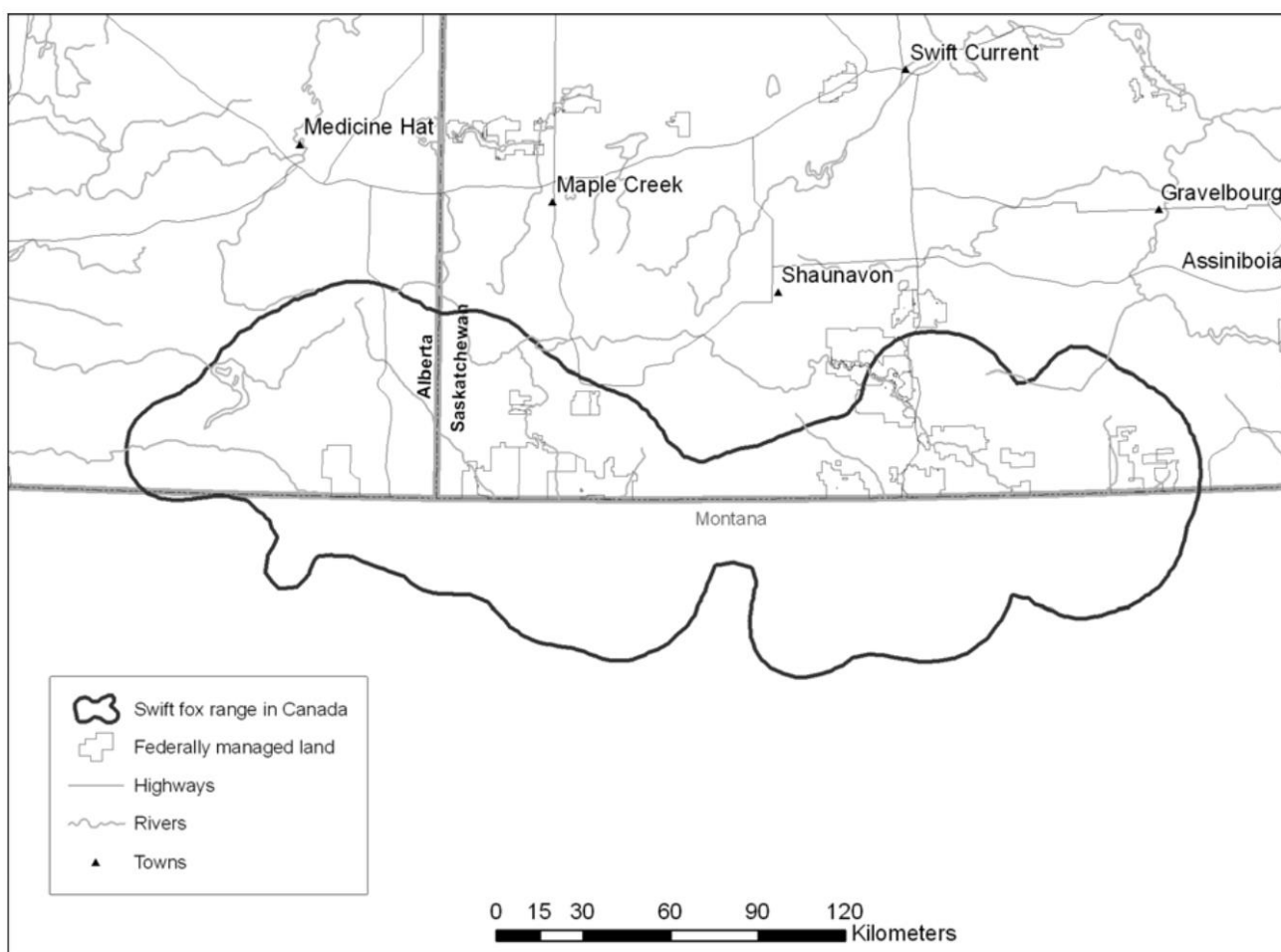
Map of current Swift Fox distribution in Canada and northern Montana produced using all confirmed locations of the species (reputable observer, road kill, live trap, or remote camera) recorded since the early 1990s less 9 points that were deemed to be outliers. The boundary shown uses a 99% kernel density estimator (map produced by Parks Canada).

Figure 12: Current estimated distributions of Swift Fox populations.

5.6.1 General Life-Cycle and Habitat Requirements

Canids in the prairies are territorial and social (e.g. coyotes, wolves, foxes). They occupy seasonal home ranges that are constrained by pup-rearing and denning during the spring and summer, and during the winter juveniles disperse from their natal range to establish new territories. Female felids and bears have similar activity periods. However, males do not stay to rear young after the breeding period.

Ungulates, such as the pronghorn and elk, are typically restricted to remnant large natural patches, as road mortality and a tendency to avoid human disturbances play strong roles in restricting movement across the landscape. Deer and moose populations are much more wide-ranging, frequently found in areas of human dominance, despite regular mortality events from traffic.

5.6.1.1 Critical Habitats

Large mammals have large minimum-area requirements and longer dispersal distances compared to small mammals. Grizzly bear home ranges are smaller in areas with greater food availability, and they increase in areas with lower resources. Protecting these large areas is a conservation challenge, especially in grassland biomes (Minor and Lookingbill 2010). Many large mammals, especially carnivores, have been displaced from the prairie landscape due to a combination of human-wildlife conflict and a poor tolerance and adaptability to land uses such as industrial development and human activity. Therefore, although some remaining habitats may be high quality, intolerant species will still avoid settling in these areas.

Pronghorn require grasses, forbs, and shrubs (particularly sagebrush) for forage and fawn bedding cover (Yoakum 2004) and are often associated with rough or rugged terrain (O2 2008b). As they are sensitive to road traffic (both as a direct source of road mortality and due to avoidance of noise and light) and to fencing, they have seen sharp declines as the human encroachment on the prairies has subdivided the naturally open and connected grassland landscape. A migratory species, archaeological evidence suggests that some North American prairie migration routes have been used for 6000 years, many of which have been lost, leading to a reduction in overall herd migration efforts (Poor et al. 2012). This has caused a disconnect in the remaining populations of pronghorn, making the remaining large prairie grasslands more important, as populations are unlikely to be replenished by outside sources.

The swift fox relies on contiguous native grasslands within its home range (Ausband and Moerhenschlager 2009). As most populations have gone extinct, reintroduction efforts play a strong role in determining the presence of Swift Fox populations. In Canada, on the northern periphery of the species historic range, remnant habitats are more limited in the resources they provide, which has led to larger home range requirements than is seen in the southern populations. As the amount of suitable habitat for reintroduced populations is limited, foxes may be more likely to disperse over large distances as populations become saturated (Moehrenschlager et al., 2007).

5.6.1.2 Isolated Habitats

In the case of wide-ranging large mammals, geographically isolated habitats may be acting simultaneously as stepping-stone habitats and as habitats supporting a viable subpopulation. Cypress Hills, for example, is a geographically isolated pocket of the montane subregion that supports a breeding population of cougars. Established cougar populations to the west re-colonized this area and their persistence and genetic diversity depends on continued dispersal from these areas. It is important to maintain this gene flow and functional connectivity. If re-colonization continues, their population structure will likely consist of geographically isolated subpopulations within an agricultural matrix. This area serves as a critical habitat for its resident breeding population at a local scale and as an important stepping stone, at a continental scale, facilitating the species' range expansion into its historical eastern range (Morrison et al. 2015).

Historically, swift foxes of the northern Great Plains of North America have been thought to be poor dispersers. Patches of optimal shortgrass prairie habitat for swift foxes are disjunct throughout the northern plains due to extensive cultivation, and populations of swift foxes may be isolated from one another because of an inability to cross a harsh cultivated matrix (Saunders et al., 1991). As the Swift Fox is less prone to wide-ranging movement, isolated habitats are unlikely to be re-colonized, making the persistence of Swift Fox populations dependent on the success of the local population.

5.6.2 Movement Patterns

Mammals can have varying dispersal strategies. Typically, an individual can be a resident, staying year-round within the same home range; a migrant, dispersing between a summer and wintering range; or a transient, maintaining temporary home ranges (Morrison et al. 2015) that vary between seasons.

5.6.2.1 Permeability of Matrix Habitats

The agricultural matrix has largely supplanted carnivores in the prairies (Northrup and Boyce 2012). Canids, for example, have varying tolerance to development intensity. Many carnivores have become displaced from the prairies by disturbed areas (Boyce et al. 2010). The wolf is the most sensitive and has become largely displaced from the landscape. Red foxes and coyotes have higher tolerance and behavioural plasticity and can be found inhabiting even the most converted urban landscapes, satisfying their resource requirements using small pockets of suitable habitats (denning in culverts, cemeteries, golf courses, and even under back decks). Mammals adapting to environments with increased disturbance (e.g. human persecution, industrial development) can switch from diurnal in natural landscapes to nocturnal behaviours in more developed landscapes to avoid peak human activity periods (e.g. grizzlies, coyotes; Boyce et al. 2010).

Grizzlies, although the prairie population is now presently extirpated (AEP 2016), are still attracted to agricultural landscapes and can be drawn into suitable habitats. However, these habitats can also act as ecological traps and result in human-wildlife conflict. Ranches close to streams with lots of edge habitat present the highest potential for human-wildlife conflict (Northrup and Boyce 2012). For species such as this, proper storage of attractants (e.g. livestock, grain) is necessary to prevent conflict and wildlife mortality. Mammals that are less tolerant to human presence will completely avoid these areas. The pronghorn, for example, avoids areas of suitable vegetation that are in proximity to anthropogenic features at a local scale, while avoiding roads and other infrastructure at a regional scale (Jakes 2015).

5.6.2.2 Long-Range Dispersal Movements

For carnivores, subadults and transients primarily disperse long distances annually during the dispersal period when they look for available resources and mates to establish territories. Resident adults occupy territorial home ranges that shift and contract between seasons. Ungulates of all ages, on the other hand, can conduct annual migrations or long-range dispersal movements from their breeding to their wintering grounds, depending on their migration strategy.

Swift foxes, for example, can disperse up to 191 km from their natal range (Ausband and Moerhenschlager 2009); however, not all individuals disperse these distances during the dispersal season. To support more individuals, the need for certain individuals to disperse is dependent on the capacity of their natal range and its surrounding habitats. Some foxes settle within 2 km of their natal range (Ausband and Moerhenschlager 2009).

Due to the risks of travelling long distances, some species will disperse longer distances at night. When traversing open habitats, a subadult transient cougar, for example, will disperse several hundred kilometres at night, conducting fast-paced nocturnal movements and shortened daytime movements to limit exposure in the matrix while searching for resources and mates. Breeding opportunities are a major factor that influences the establishment of transient cougars in more permanent home ranges (Morrison et al. 2015).

Pronghorn, the flagship species for connectivity issues in the prairies, are diurnal migrants. They are at the periphery of their northern range and migration is vital to their survival of winter conditions (Poor et al. 2012; Jakes 2015). In Alberta, they can switch strategies between migrant (55%) and resident (54%) depending on the environmental conditions (Jakes 2015). In the spring, pronghorn have more predictable migration routes, moving between high quality foraging habitat (primarily forbs (e.g. silver sagebrush) and grasses), freshwater sources, and their breeding grounds (Poor et al. 2012; Jakes 2015). During the spring, their movements are slow and sinuous, they take time to, forage and stopover to meet resource requirements for reproduction (Jakes 2015). Although they primarily stopover during spring migrations, they also stopover during the fall in areas of high-quality foraging habitat, with lower industrial disturbance density (Jakes 2015). During the fall, they follow hydrological features, (Poor et al. 2012; Jakes 2015) conducting linear and rapid movements to increase their survival (Jakes 2015). However, they have been observed conducting less predictable exploratory movements

during variable winter conditions (Poor et al. 2012). Because winters vary annually and pronghorn can change their movements in response to changing conditions, it is important to identify migration corridors and bottlenecks from multiple years of data (Poor et al. 2012).

5.6.2.3 Localized Movements within the Home Range

During the spring and summer, canids, including the Swift fox, occupy constrained territorial home ranges with focal activity clusters between their den and foraging areas (Figure 10). The size and selection of habitats within these home ranges can differ by gender. In Cypress Hills, male cougars occupy open habitats on the edges of Cypress Hills and females occupy treed habitats with better cover. Both sexes select for rugged terrain and riparian habitats, travelling only at night to traverse or conduct exploratory movements through the agricultural matrix (Morrison et al. 2015). Female grizzlies also have significantly smaller home ranges than males (e.g. Morehouse and Boyce 2016).

Species have fundamental daily behavioural patterns (Cushman et al. 2005; Boyce et al. 2010) that can be disrupted spatially and temporally to avoid human activity. In more developed landscapes, species can switch to nocturnal behaviours to avoid peak human activity periods. Grizzlies in southwestern Alberta have home ranges composed primarily of private properties. During the day, they bed down and avoid open habitats. At night, they avoid open areas and are more active, preferring to travel along cutlines, trails, and houses (Northrup and Boyce 2012). In southern Alberta, wolves (Boyce et al. 2010), coyotes, and cougars (Morrison et al. 2015) also switch from natural diurnal patterns to nocturnal activity.

Ungulates in the prairies are diurnal, primarily active during the daytime. Their dominant daily natural activity patterns do not switch to nocturnal due to human presence. Elk, for example, remain active during the day with peak activity occurring during the evening (Boyce et al. 2010). It is important to consider temporal activity shifts when planning for large mammals as it represents a crucial aspect of their strategy to coexist with human activity and development on the landscape. Moreover, when analyzing GPS telemetry data for localized or dispersal corridors, it is important to filter for periods when this movement occurs.

Canids are social and territorial. Individuals of the same family are permitted to settle in the same territory, if resources are available, whereas transient individuals are not. This territoriality can extend to other species as well, wolves, for example, defend their territory against coyotes, with whom they compete for resources. Female cougars and grizzlies share limited space, allowing spatial overlap in their home ranges with siblings (Elbroch, et al. 2016). Canids often use natural and anthropogenic boundaries to mark their home ranges, such as roads, canals, and fence lines.

5.6.3 Movement Facilitators

Since many large mammals are resident species that do not hibernate (excepting bears), they are active and present on the landscape when the structure and composition of the landscape changes between seasons. Therefore, there is a seasonal aspect to natural barriers. In the winter, large rivers and lakes that freeze allow them to travel over features that would previously require swimming or wading ability.

However, for many species, the low-traffic volume on the tracks does not present a barrier and for some, the tracks can facilitate movements (e.g. coyote).

5.6.4 Movement Inhibitors

Roads and fencing act as barriers for all large mammals. Large mammals are more impacted by these barriers than small mammals because they traverse longer distances and, therefore, cross them more often (Minor and Lookingbill 2010). Major highways with high-traffic volume serve as barriers to dispersal for most large mammals. Highways with high-traffic volume of over ≥2,000vehicles/day are complete barriers to pronghorn (Seidler et al. 2014; AEP 2016). Mammals that change their activity patterns to nocturnal behaviours can cross busy highways more easily when they have lower traffic volume at night. Therefore, the relative permeability of these barriers is temporal and likely more permeable at night. Carnivores with behavioural plasticity, such as the coyote, red fox, and grizzly, deliberately adapt their behavioural patterns to avoid peak human use of roads to cross at night (e.g. Boyce et al. 2010).

Rail lines are partial barriers that are mostly permeable and can lead to mortality for species that become trapped and killed on the tracks, either by the surrounding fencing (e.g. pronghorn can become trapped by deep snow and fencing) or by their escape strategy (e.g. grizzlies run in a straight line down the tracks). However, for many species, the low-traffic volume on the tracks does not present a barrier and for some, the tracks can facilitate movements (e.g. coyote).

Fencing in the prairies can incidentally (e.g. to restrict livestock) or purposely restrict wildlife movements (e.g. to protect crops and to prevent vehicular collisions; Gates et al. 2012). Fencing design and density can cause complete or partial restriction of movement depending on the species. Typical fencing associated with agricultural areas acts as a complete barrier for pronghorn, who attempt to pass under the wires (Seidler et al. 2014). However, for elk and deer who jump over these fences, they are only a partial barrier or not one at all. This type of fencing is generally only a partial barrier for carnivores and specific designs are required to restrict their access to attractants to reduce wildlife conflict. If fencing cannot be completely removed from the landscape, replacing barbed wire with smooth wire, lowering fence height, and raising the lowest wire strand allows pronghorn to pass through (Poor et al. 2012).

When roads that act as significant barriers (complete barriers and high wildlife mortality) cannot be moved or removed, wildlife overpasses and underpasses should be considered to prevent population isolation and viability. In locations where large mammal movement is bottlenecked or where there are localized wildlife mortality hotspots, considerations should include reduced road speeds, fencing to guide wildlife into more appropriate crossing areas, and warning signs to inform drivers to be vigilant and reduce their speed. Temporary or permanent signs informing drivers of daily (e.g. crepuscular movements of cougar, ungulates, and canids) and seasonal (e.g. migration, dispersal) peak activity periods should be posted in crossing areas.

5.7 Small Mammals

Small mammal species are widely distributed across the prairie landscapes, having adapted to human agricultural and urban environments. There are many kinds of small mammals found in the prairie landscape: rodents (e.g. mice, voles, ground squirrels, beaver), mustelids (e.g. weasels, skunks, badgers), lagomorphs (e.g. hares, rabbits), and bats. Although foxes are small mammals, they have been included in the Large Mammals section due to the behavioural, dispersal, and life history similarities they share with other canids.

Although plentiful, connectivity between populations of these mammals is frequently restricted by road fragmentation. Small mammals provide a substantial portion of the diet of carnivore species in the prairie, and changes to the abundance of these species will in turn affect the survival of the species who prey upon them. Their rapid generation times mean that populations tend to fluctuate substantially between years, in response to changing environmental conditions, food availability and predator population dynamics. Small mammals are an effective focal group for evaluating restoration programs because of their sensitivity to habitat change (Stone 2007). Moreover, small mammals form a crucial link in trophic food webs of grassland ecosystems and can have strong top–down influences on vegetation (Getz & Brighty 1986, Howe & Lane 2004, Moro & Gadal 2007). Small mammals also are important prey for predators, Richardson's Ground Squirrel, for example, typically make up more than 80% of the diet of predators such as the American Badger, and can experience mortality rates of up to 50% due to predation during hibernation. The extirpation of the back-tailed prairie dog from Alberta, a keystone species (COSEWIC 2009) lead to the subsequent extirpation of the black-footed ferret which preys upon it, an example of the degree to which these populations interact with one another (AEP 2002).

When attempting to restore grasslands for small mammals managers should focus on the connectivity provided by linear habitats. In agricultural ecosystems, hedgerows, roadside ditches and grass waterways located near recently restored grasslands promote early colonization by grassland species of small mammals. Land managers should consider the connectivity provided by these linear habitats when selecting parcels for restoration. Restoration practices that create a mosaic of grasslands of various ages could sustain a diversity of small mammals on landscape scales.

Group	Common Name	Latin Name	Status
Rodents	Richardson's ground squirrel	*Urocitellus richardsonii*	Not At Risk

	Western harvest mouse	*Reithrodontomys megalotis*	Special Concern
	Ord's kangaroo rat	*Dipodomys ordii*	Endangered
	North American beaver	*Castor canadensis*	Secure
Mustelids	Long-tailed weasel	*Mustela frenata*	May Be At Risk
	American badger	*Taxidea taxus*	Data Deficient
	Striped skunk	*Mephitis mephitis*	Secure
Lagomorphs	Snowshoe hare	*Lepus americanus*	Secure
	White-tailed jackrabbit	*Lepus townsendii*	Secure
Bats	Hoary bat	*Lasiurus cinereus*	Sensitive

5.7.1   General Life-Cycle Habitat Requirements

Small mammals are typically year-round residents of Alberta. They do not migrate, instead, they exhibit a variation of behavioural adaptations to survive the winter including hibernation, torpor, and remaining active. Most of these small mammals burrow during the winter below the snow. Rodents may not surface until the spring. Beaver, muskrat, porcupine, and weasels do not hibernate and remain active during the winter (AEP 2015). Small bats congregate and overwinter in hibernacula, at which time they are vulnerable to predation and the spread of disease. While white-nose syndrome has not yet been discovered in Alberta hibernacula (AEP 2017), it remains a growing concern elsewhere in the continent.

5.7.1.1 Critical Habitats

Burrowing animals enhance biodiversity and create a unique mosaic of patch types over multiple temporal and spatial scales through habitat disturbances associated with burrowing (Davidson and Lightfoot 2006). The Richardson's ground squirrel, a burrowing mammal, is a ubiquitous keystone species in Alberta that influences overall prairie ecosystem biodiversity. Their burrows provide critical habitat (e.g. hibernacula) for other species that cannot dig (e.g. burrowing owl, various species of snakes; MULTISAR 2015).

The long-tailed weasel is a generalist whose distribution and movement behaviour is dependent on prey availability (Gehring and Swihart 2004). Predation by the long-tailed weasel provides strong control of rodent populations that damage crops and stored grains (COSEWIC 1993). Habitat loss and drainage of wetlands limits the availability of suitable habitat for weasels and is responsible for their decline.

The American Badger is a predator feeding mainly on Richardson Ground Squirrels, often storing carcasses for future meals in burrows. They require open native grasslands with moderately course or fine soils with little woody cover (MULTISAR 2015). Richardson's ground squirrels are also an important prey species (≤ 80% of predator diets) that directly influences the abundance of specialized predators, such as the ferruginous hawk, the American badger, and the long-tailed weasel. Richardson's ground squirrels are also an important prey species (≤ 80% of predator diets) that directly influences the abundance of specialized predators, such as the ferruginous hawk, the American badger, and the long-tailed weasel.

Many other small mammal species are more opportunistic generalists: they can live in a variety of conditions, and make their living foraging from human resources such as farms and urban food waste. Richardson's ground squirrels are remarkably adaptable and can burrow in highly modified landscapes, such as city parks, perennial crop fields, grazed pastures, and the edges of cultivated fields. Jackrabbits are frequently seen throughout the urban core of most Alberta cities.

5.7.1.2 Isolated Habitats

Because of their limited dispersal abilities, smaller mammals are more likely to be limited by connectivity to available habitats than availability of habitats per se (Minor and Lookingbill 2010). Useful conservation strategies to functionally connect isolated habitats within a network include protecting additional land or increasing connectivity of nearby habitats through restoring stepping stone habitats and linear corridor features in the landscape.

Ord's kangaroo rat populations are rare and difficult to detect (Gummer and Robertson 2003), confounding research efforts. They are dependent on open, active sand dunes and sandy habitats. In Alberta, their populations are small, localized and geographically isolated by distance (i.e. 270km) from those in Montana (Environment Canada 2012). There is only one documented population on the south side of the South Saskatchewan river, which has likely been colonized by Saskatchewan populations, as kangaroo rats cannot swim (Gummer and Robertson 2003). There is not enough suitable habitat in Alberta to support self-sustaining populations (Gummer and Robertson 2003), which is compounded by their low dispersal ability of an average of 1.6 km and a maximum of 3.2 km (Brands 2016). Therefore, even if suitable sand dunes are available, they may not be reachable and are therefore functionally isolated. Strategically restoring stabilized dunes that can act as stepping stones at a local scale can simultaneously increase available habitat, dune network connectivity, and metapopulation stability (by rescue effect from subpopulations; Brands 2016). Restoration and translocations are underway to assess the potential of these methods to recover these populations (Bender et al. 2010; Brands 2016). Regional management of kangaroo rats should, therefore, include geographically isolated suitable and potential habitats for restored functional connectivity.

5.7.2 Movement Patterns

5.7.2.1 Permeability of Matrix Habitats

Small mammals interact with the landscape at a smaller scale than large mammals and a less benevolent matrix can greatly reduce their dispersal ability. Intensely cultivated landscapes are favourable to generalists but often detrimental to small mammals such as Ord's kangaroo rat that are rare and require specialized habitat (Pena et al. 2003). When landscapes are restored, small mammal communities shift from a dominance of generalists to increasing numbers of specialists (e.g. Mulligan 2012).

5.7.2.2 Long-Range Dispersal Movements

Small mammals with localized populations are expected to be more vulnerable to climate change due to their limited dispersal ability. Long-distance species movement is generally multi-generational, rather than the result of individual migratory behaviour. This means that connectivity between significant areas is fundamentally a matter of population viability in the intervening spaces, rather than simply a matter of ensuring movement through these spaces.

Road verges can act as dispersal corridors for kangaroo rats, allowing them to disperse farther than their maximum (i.e. 9.5 km) from grassland habitats (i.e. 3.2 km). However, these strips of vegetation are examples of landscape features that can simultaneously function as conduits to better habitat, and habitat sinks should kangaroo rats settle in these areas (Brands 2016).

Small mammals often use linear features in the landscape to facilitate movements such as roads, rights-of-way, hedgerows, and roadside/drainage ditches. Small rodents (e.g. voles, mice) can thrive at the interface between different habitats, using them simultaneously to nest and travel.

Weasels move at a greater rate in the winter compared to the summer (Gehring and Swihart 2004). There is evidence of a migration route along the eastern slopes of the Rocky Mountains used by bats from across Alberta and beyond (Baerwald et al. 2014).

5.7.2.3 Localized Movements within the Home Range

Many rodents are active at night (AEP 2015). This can make them sensitive to human disturbances that are frequently in use during the night, such as urban centres, industrial plants, and other well-lit and noisy land uses.

Small mammals generally have small home ranges. They can persist in pockets of isolated suitable habitats (e.g. road medians, right-of-way). However, for many, habitats such as these act as habitat sinks, by drawing wildlife into areas with a high likelihood of mortality. However, fencerows, hedgerows, drainage ditches and other linear features provide shelter during movement and are typically associated with greater overall landscape connectivity and population persistence (Tattersall et al. 2002).

The Prairie long-tailed weasel is a grassland parkland species whose range is limited by the boreal forest and the Rockies to the west. Tolerant to human activity and development, the weasel is common throughout its range and limited by the availability of free-standing water and the presence of prey species (Gehring and Swihart 2004). In Alberta, the highest densities are found throughout the aspen-grassland habitat connecting Edmonton to the US border with a patchy distribution in adjacent areas to the west and east.

During the first year of community assembly following restoration, the abundance of Microtus voles depended on spatial connectivity provided by linear habitats (roadside ditches and grass waterways) within 300 m, which probably served as temporary habitats and movement corridors (Mulligan 2013).

5.7.3 Movement Facilitators

Weasels and deer mice use culverts for passage, although traffic volume and noise affects their use of these structures (Clevenger et al. 2001). For many small and medium-sized mammals, drainage culverts can mitigate the potentially harmful effects of busy transport corridors by providing a vital habitat linkage. To maximize connectivity across roads for mammals, future road construction schemes should include frequently spaced culverts of mixed size classes and should have abundant vegetative cover present near culvert entrances. (Clevenger et al. 2001).

Species that are active during the winter, such as coyotes, experience a more connected landscape due to frozen conditions of rivers, streams, and lakes (Lamy 2015).

For species that avoid roads and are not disturbed by traffic, they can have positive effects by reducing predator density in the area (Fahrig and Rytwinski 2009).

To optimally facilitate the movement of small mammals, wildlife crossing structures require characteristics that are more attractive to small animals (e.g. smaller diameter, more vegetative cover, low vehicular traffic volume). They should be placed within appropriate distances from essential habitats that reflect the species' dispersal ability and home range size (McDonald and St Clair 2004). The perceptual range of these smaller mammals likely limits their ability to use crossing structures designed for large mammals (Beier and Loe 1992).

5.7.4 Movement Inhibitors

Due to their size, small mammals are not impeded by most fencing designs, excluding solid retaining walls. However, natural features can be barriers to movement. Open water such as rivers, streams, and lakes can block movement, depending on the species' ability to swim. Ord's kangaroo rats, for example, cannot swim and the south Saskatchewan river is therefore a complete barrier (Gummer and Robertson 2003), whereas voles are excellent swimmers.

Roads can cause direct mortality through collisions and habitat loss due to construction and disturbance avoidance.

Bat populations have been shown to be impacted by windfarm structures (Baerwald and Barclay 2009) and mortalities at a single windfarm can have continental repercussions for the species' population and the ecosystems they inhabit (Baerwald et al. 2014). For example, hoary bats killed in southwestern Alberta originate from farther north and silver haired bats are potentially migratory bats from large catchment areas.

PLANTS

There are approximately 3,770 species of plants in Alberta (ANPC 2015), composed of vascular and non-vascular plants (e.g. lichens, mosses). Very few of these species are listed by COSEWIC as At Risk or Endangered, and of those, none are lichens and mosses. However, 205 vascular plants, 52 lichens, and 32 mosses in the grasslands region are considered, by Alberta Parks, rare or of conservation concern due to threats to their populations or habitats (ACIMS 2016). In 2001, almost 125 (27%) of rare vascular plants were found within the Grasslands Region, 55 of which are found only in prairie landscapes (ANPC 2001).

Grassland Vascular Plants

Grasses have several features that make them well suited to the harsh prairie climate, including the long, cold prairie winters and dry, hot summers. Grasses typically have extensive root systems up to 4 m deep, allowing consistent access to soil moisture and nutrients. Tough stems and narrow leaves limit water loss and reduce impacts from grazers. Grass species such as the blue grama grass, northern wheatgrass, and needle-and-thread grass are common grasses in native prairie.

While grass is the predominant vegetation of the prairie, other vegetation elements, such as trees, shrubs, forbs and herbs, are also an important part of plant diversity. Trees and shrubs, such as the narrow-leaf cottonwood, silver sagebrush, and prickly rose are commonly found in depressions, along creeks, and in coulees and ravines where there is enough moisture to support their growth, and where they are sheltered from the wind to prevent evaporative water loss.

Wildflowers are also common throughout the native prairie landscape. Beginning in the early spring with the first purple blooms of species such as the prairie crocus and three-flowered avens, wildflowers bring added diversity to the prairies during the growing season. Native grassland plant communities support significant ecological processes and functions, such as nutrient cycling, capture and slow release of water, soil preservation, and wildlife habitat, in addition to providing forage for grazing livestock. Preservation of native prairie habitat will help maintain grassland plant biodiversity and important ecosystem functions.

Non-Native Plants

Non-native plants are those species that have been introduced, intentionally or otherwise, into new areas beyond their natural habitat. While not all non-native species represent a threat to biodiversity, non-native species can become a major ecological concern. In prairie ecosystems, non-native plants can have multiple detrimental impacts. For example, non-native species compete with and displace native plant species, altering wildlife habitat and reducing local biodiversity. Once established, non-native plants can alter soil and water cycles, potentially increasing soil erosion and decreasing water availability. The nutritional value of non-native plants for grazing livestock and wildlife is lower compared to native plants, and some invasive species are known to be toxic to grazers (e.g. common tansy, tall buttercup, leafy spurge). Overall, non-native plants cause a significant loss in the productivity of Alberta's rangelands and croplands. It is estimated that weeds cost Canadians $2.2 billion annually in reduced crop and pasture productivity (ABMI 2015).

The ABMI found 38 non-native plants in the Prairie Region (ABMI 2015). Non-native plants were detected at all ABMI sites sampled in the region, and an average of nine non-native species were present at each site. In Alberta's Prairie Region, a wide variety of non-native species have been intentionally introduced for agricultural purposes, as crops and forage for livestock. Common dandelion, the most abundant non-native plant, was found at 86% of ABMI sites in the region. Two of the species detected are listed under the Alberta Weed Control Act, creeping thistle and perennial sow-thistle.

5.7.5 General Life-Cycle and Habitat Requirements

Vascular plants disperse using seeds and undergo several life stages: seed establishment, germination, growth, reproduction, pollination, and seed dispersal. Mosses, on the other hand, can disperse using spores and have different life stages: spore establishment, germination, growth, reproduction, and spore dispersal. During reproduction, they can reproduce sexually and/or asexually. Sexual reproduction requires spore and seed dispersal, whereas asexual reproduction typically does not; however, this depends on the species.

Vascular plants and mosses can also be annual (complete life cycle within one year), perennial, (life cycle is longer than two years), and ephemeral (a very brief life cycle during favourable conditions). The life span of a moss is much more variable than vascular plants, varying from a few weeks in ephemerals to hundreds of years (During 1979).

5.7.5.1 Critical Habitats

Flowering plants can be associated with a variety of habitats in the grasslands region including native grasslands, sand dunes, river valleys, and sparsely vegetated coulees, depending on their habitat requirements. The populations of many of these species in Alberta can fluctuate widely from year to year due to their dependency on favourable germination and moisture conditions (e.g. tiny cryptantha, small sand verbena). Some species require disturbed ground to grow (sandy to silty substrates), but will not persist if the area is too frequently disturbed (e.g. cultivated, active sandbars, eroding slopes/cutbanks). Grazing can be beneficial for species that are dependent on sand dunes as grazing destabilizes surrounding vegetation communities and keeps sand dunes active (e.g. Western Spiderwort, sand verbena). In the past, 20% of rare plants in the grasslands region were associated with sandy soils (Wallis 1987).

Mosses have highly specialized habitat preferences and can be found in habitat niches at the base of trees and shrubs, around creeks and wetlands, in rocky crevices, woodland pockets, and in native prairies. Generally, the smaller the habitat niche, the rarer the species, such as rocky crevices (Frahm 2008, which form biological soil crusts, which slow down overland surface flow, increasing soil infiltration and soil moisture and stabilizing soils from erosion (ABMI 2015). For mosses associated with the base of trees (*Orthotricum*), the connectivity of tree patches is the single most important variable predicting recent colonisations of *Orthotricum speciosum* in Finland (Snall et al. 2003) – *Orthotricum pallens* and *pumilum* are two mosses found in the Foothills Fescue region (ACIMS 2015).

Generally, literature on mosses and vascular plants, specific to the grassland region, is lacking information regarding habitat requirements, connectivity, life history, status, occurrence, and population viability.

5.7.5.2 Isolated Habitats

Geographically isolated habitats that are suitable for establishment may be within the regular dispersal range of some species and the infrequent dispersal range of others. These isolated habitats are important for the establishment of new populations and, depending on their configuration, can provide connections to existing populations. However, these open patches could also be colonized first by more highly mobile invasive species, promoting their spread. Geographically isolated native remnants between property lines might also act as plant refugia for some species (Smart et al. 2001).

5.7.6 Movement Patterns

Plants either conduct a passive or an active dispersal strategy to propagate their seeds, pollen, or spores. Passive dispersers can use animals, wind, and water as vectors for dispersal. Active dispersers can self-propagate within a certain radius from the parent plant. Some plants, which reproduce asexually, are not reliant on dispersal mechanisms for reproduction and dispersal, and instead grow directly from the parent plant (e.g. clonal reproduction). A single plant can simultaneously employ multiple dispersal strategies, but may be better designed for some. The sand verbena, for example, has dry seed-like fruits enclosed in papery, veined wings that assist wind dispersal into open sandy habitats (MULTISAR 2012), whereas the slender mouse ear cress' seeds do not have wings, and its dispersal ability is therefore more limited (MULTISAR 2015).

5.7.6.1 Permeability of the Matrix

The cultivated matrix is generally unsuitable for establishment of native plants in the grassland region. Many plants initially require open or disturbed ground for seed establishment. A lack of open patches in the landscape is, in part, due to changes in the natural disturbance regime. Historically, there were more burnt and overgrazed patches that reduced the number of competitive species on the landscape and provided more areas that were suitable for establishment (e.g. slender mouse-ear-cress; SAR). Therefore, during seed establishment and

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dispersal, even native landscapes without open patches can be considered inhospitable and part of the matrix, inhibiting the expansion of the plant's range and connections to neighbouring populations.

Other species may establish in areas that have been disturbed by human activity (e.g. industrial oil and gas, overgrazing), but plants that do settle (e.g. small-flowers sand-verbena, tiny cryptantha) eventually die because these habitats only provide suitable conditions over a short-term period during establishment and not for the full life-cycle, thereby acting as ecological traps.

5.7.6.2 Long-Range Dispersal Movements

Vascular plants have variable dispersal abilities and strategies. Those that are typically capable of dispersing the farthest are those that depend on passive dispersal vectors. Those that rely on active dispersal by self-propagation and gravity generally do not disperse farther than the immediate vicinity of the parent plant (e.g. tiny cryptantha, western blue flag, soapweed, slender mouse-ear-cress, western spiderwort), unless additionally assisted by winds (e.g. soapweed, western blue flag). Soapweed, for example, has smooth seeds and even with wind as an occasional vector, it does not disperse farther than 100 m from its parent plant, whereas other species' seeds may, albeit infrequently, cover considerable distances by wind dispersal (e.g. western blue flag). Using its obligate pollinator, the Yucca moth (*Tegeticula yuccasella*), which consumes soapweed seeds, can disperse farther, but not long distances, as the moth is considered a weak flyer (AESRD 2013). Soapweed primarily reproduces asexually and a lack of sexual reproduction and seed dispersal with its obligate pollinator is thought to hinder its expansion into new habitats. Moreover, Soapweed is not just reliant on the yucca moth, the moth is also reliant on the soapweed's seeds, much like the non-pollinating yucca moth, *Tegeticula corruptrix;* and the five-spotted bogus yucca moth, *Prodoxus quiquepunctellus* – which are both Endangered. For plants such as these, it is unlikely that nearby populations will become connected and unlikely that neighbouring populations would perform any rescue effects (e.g. Western Spiderwort).

Some species may only migrate beyond their current range under anthropogenic passive dispersal, by humans transporting species for gardening (e.g. soapweed), under assisted migration (e.g. northern blazing star and long-leaved bluets; Penderson et al. 2014), or by getting caught up in vehicles (e.g. soapweed). Generally, there is a lack of information regarding many species' seed productivity, seed bank longevity, and dispersal rates and distances (e.g. tiny cryptantha). Further information is required to gain an understanding of population viability over time.

Mosses (Bryophytes) are non-vascular plants that disperse by small (µm) unicellular spores that are passively dispersed by wind, water, and insect or animal vectors (Frahm 2008). *Splachnum* mosses, such as the yellow collar moss (*Splachnum luteum*), found in the Dry Mixedgrass region (ACIMS 2015), are highly specialized to moist nutrient rich substrates, primarily the dung of large herbivores (Frahm 2007), usually moose. Its sticky spores attach to insects, which are attracted to the dung before the insects disperse. Other species rarely produce spores, such as *Syntrichia caninervis*, a desert moss found in the Dry Mixedgrass region (ACIMS 2015), and therefore, their low reproductive output constrains their dispersal ability (Smith and Stark 2014). However, many mosses have high potential for dispersal due to dispersal via small spores, but have restricted ranges globally due to a variety of limiting reasons (e.g. high habitat specialization, poor reproductive output, lack of occurrence of one sex, present as a remnant population; Frahm 2008).

5.7.6.3 Localized Movements within the Home Range

Plants do not conduct localized movements outside of their dispersal or reproductive season and many species are not capable of dispersal beyond close range of their parent plants. Disturbances such as tilling, infrastructure development, and road construction may produce movement of plant material as topsoil is transported, vegetative growth following these events may result in the spread of plant species outside of their typical dispersal distance.

5.7.7 Movement Facilitators

As plants adopt a wide variety of dispersal mechanisms, the factors which facilitate their movement will vary substantially. These 'dispersal vectors' may be biotic factors, such as birds and mammals, or abiotic factors,

such as the wind or water. Biotic dispersal factors will show similar connectivity patterns as those exhibited by the species which carries the seed (either attached to the coat, like burrs, or through the digestive tract, and later excreted). Abiotic factors such as the wind will show some degree of Human-mediated transport is also possible, though chiefly recognized when discussing the spread of invasive plant species (along roadways, between fields, and between watercourses and lakes).

5.7.8 Movement Inhibitors

When animal vectors transport seeds, corridors and barriers for the seed disperser play a similar role for the plant. With water as a vector, dispersal of seeds is likely inhibited by a lack of natural range of variation in water flow due to dams or diversions, which can reduce the number of larger floods, but increases the number of smaller ones, thereby reducing suitable conditions for seed establishment (e.g. cottonwoods). With wind as a vector, seeds can be transported into unsuitable establishment areas with impenetrable surfaces (e.g. roads, urban areas) or native or natural areas that have high species competition. Topography may also limit wind dispersal, since seeds may not be able to pass over features like hills, mountain ranges, urban areas, and rivers. Waterborne dispersal is impacted by alterations to the watercourse, as locks and dams interfere with natural drainage patterns across the landscape.

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