

**Assessment of grizzly bears (*Ursus arctos*) north
of the Canada-U.S. border and their relationship
to populations in the lower-48 States**



Michael Proctor

Andrea Morehouse

**Prepared for the U.S. Fish and Wildlife Service
Grizzly Bear Recovery Office, Missoula, Montana**

January 2021

Table of Contents

Introduction	7
British Columbia Overview.....	9
British Columbia – U.S. border Grizzly Bear Population Units	12
North Cascades	13
Granby-Kettle GBPU	17
South Selkirk GBPU	18
Yahk GBPU	26
South Purcell GBPU	30
Flathead GBPU	30
South Rockies GBPU	33
British Columbia Summary	34
Connectivity.....	34
Abundance	35
Motorized Access Management	36
Alberta Overview.....	37
South of Highway 3 – BMA 6	40
Yukon, Northwest Territories, and Nunavut	45
Alaska.....	45
Literature Cited	47

List of Figures

Figure 1: Grizzly bear distribution in western North America with abundance estimates. Adapted from Proctor et al. (2021a).	7
Figure 2: a) Grizzly Bear Population Units across B.C. ranked for conservation status using the Nature Serve threats assessment protocols (Morgan et al. 2020) and, b) road density by landscape unit across British Columbia (Adapted from Proctor et al. 2020).	10
Figure 3: Fragmentation of grizzly bears, in the trans-border region spanning the Canada-U.S. border. Yellow dotted lines represent primarily female fragmentation, but with reduced male connectivity as well. Numbers are population estimates within these ‘biological’ subpopulations (adapted from Proctor et al. 2012).	12
Figure 4: Grizzly Bear Population Units along the Canada-U.S. border in southern British Columbia, their estimated population size, and adjacent U.S. Recovery zones (B.C. Government 2020, Proctor et al. 2021b).	13
Figure 5: North Cascades region including the neighbouring Grizzly Bear Population Units to the northwest. The red dotted line is a data-based approximation of the grizzly bear distribution north of that line (Apps et al. 2014). The distribution in the North Cascades is unknown.	14
Figure 6: Road density classes in the North Cascade Grizzly Bear Population Unit of southwestern B.C.	14
Figure 7: Granby-Kettle Grizzly Bear Population Unit along the Canada-U.S. border immediately northwest of the U.S. South Selkirk Recovery Zone. Habitat selection estimated by resource selection functions (green), grizzly corridors, (yellow), and huckleberry patches (purple) are shown (Proctor et al. 2015, 2021b).	17
Figure 8: a) South Selkirk Grizzly Bear Population Unit along the Canada-U.S. border immediately north of the U.S. South Selkirk Recovery Zone. Habitat selection estimated by resource selection functions (green), grizzly corridors, (yellow), and huckleberry patches (purple) are show, (Proctor et al. 2015, 2021b), and b) protected lands in the South Selkirk Grizzly Bear Population Unit.	19

Figure 9: a) An example of resource road management on Nature Conservancy of Canada lands in the South Selkirk Mountains as a mitigation for backcountry mortality and to increase habitat effectiveness (adapted from Proctor et al. 2018). Public access was controlled around good huckleberry patches, and this resulted in increased female habitat use, density, and realized reproductive output (fitness). Adapted from Proctor et al. (2018), and **b)** Grizzly bear density in the South Selkirk Grizzly Bear Population Unit. Red oval indicated are of highest density that corresponds to the upper right red oval in a) where access management has been applied by the Nature Conservancy Canada and huckleberry patch density is high (Proctor et al. 2021b).20

Figure 10: a) Road density categories within ‘Bear Management Units’ (created by the Trans-border Grizzly Bear Project to help understand road access, these are not legal entities) across the South Selkirk, Yahk, South Purcell and Central Purcell Grizzly Bear Population Units in southeastern B.C. Adapted from MacHutchon and Proctor 2016). Colors are open roads buffered by 500 m, and **b)** Percentage of secure habitat (> 500m form an open road) across the same Bear Management Units.21

Figure 11: a) Research-identified grizzly bear corridors in the trans-border Canada-U.S. region (Yellow) connecting higher quality habitat patches (green). The black arrows represent the best corridor option connecting the U.S. South Selkirk grizzly bears to the larger Canadian population in the Purcell Mountains through the Creston Valley (red circle) and **b)** Close up of the Creston Valley showing the best linkage habitat (red flames) in relation to connectivity land purchases by the Nature Conservancy Canada (NCC, blue polygons, adapted from Proctor et al. 2018).22

Figure 12: a) Conflict-related human-caused grizzly bear mortality in the Canadian South Selkirk Grizzly Bear Population Unit prior to the instigation of connectivity mortality reduction management actions, **b)** mortalities after the initiation of mortality reduction management, and **c)** human-caused mortality in the adjacent valley to the east where connectivity mortality reduction management was not applied with the same intensity as in the Creston Valley area (adapted from Proctor et al. 2018).23

Figure 13: Example of grizzly bear (*Ursus arctos*) movement and gene flow across the Creston Valley from the South Purcell Mountains to the previously isolated South Selkirk population in the Canada-U.S. trans-border region. Example is a family pedigree where offspring all share 1 allele from each parent across 21 loci. Lines connect offspring to their parents. Dot locations represent each bear’s capture or sample location. In this extended family, Bob and Maeve produced offspring Cpt. Hook who moved from the South Purcell into the South Selkirk

Mountains where he mated with 5 separate females yielding six offspring (1 of the blue dots for male offspring represents 2 offspring sampled at the same location). Adapted from Proctor et al. 2018.....24

Figure 14: a) Cumulative evidence of inter-population grizzly bear (*Ursus arctos*) movements and gene flow (breeding events after movements) prior to 2006 and b) after mortality reduction management was applied post-2006 in the Canada-U.S. trans-border region of northwest Montana, northern Idaho, and southeast B.C (adapted from Proctor et al. 2018).25

Figure 15: Yahk and South Purcell Grizzly Bear Population Units along the Canada-U.S. border immediately north of the US South Selkirk Recovery Zone. Habitat selection estimated by resource selection functions (green), grizzly corridors, (yellow), and huckleberry patches (purple) are shown (Proctor et al. 2015, 2021b).27

Figure 16: An example of male mediated gene flow across B.C. Highway3 in the Purcell Mountains. Adult male Vern (red dot) mated with females (green dots) producing various offspring (smaller dots) north and south of B.C. Highway 3. Dot location are individual's capture or hair sample locations.....28

Figure 17: Cumulative non-hunt human-caused grizzly bear mortality in the Canada-U.S. trans-border area between 1984 - 2017. Blue dots are front country mortalities and dark red dots are backcountry mortalities. Red is modeled mortality risk.29

Figure 18: The pattern of access management applied in the international Yahk/Yaak ecosystem a) shows the total roads in both the U.S. and Canadian portions, and b) the U.S. portion show the open roads after access management has been applied.....29

Figure 19: Flathead and South Rockies Grizzly Bear Population Units along the Canada-U.S. border immediately north of the U.S. NCDE Recovery Zone. Habitat selection estimated by resource selection functions (green), grizzly corridors, (yellow), and huckleberry patches (purple) are shown (Proctor et al. 2015, 2021).31

Figure 20: Coal mines in the Flathead Elk Valleys in southeast British Columbia.....34

Figure 21: Grizzly Bear Management Areas (BMAs), (b) Core and Secondary habitats (adapted from Nielsen et al. 2009), and (c) Road density categories by Grizzly Bear Watershed Units across 7 BMAs in western Alberta (AEP 2016, adapted from Proctor et al. 2020).38

Figure 22: Grizzly bear management unit north of the Canada-U.S. border in southwest Alberta relative to the NCDE Recovery zone.41

Figure 23: Increasing use of agricultural lands by grizzly bears to the east of the Rocky Mountains and foothills in southwest Alberta. Occurrence records (i.e., complaint data) show an eastward expansion over time (a, c). Photo (b) provided by Lyle Lester, Alberta Solicitor General. Adapted from Morehouse and Boyce (2017).43

Figure 24: Reported grizzly bear attractant (a) and livestock (b) incidents before and after the implementation of conflict reduction management by the Waterton Biosphere Reserve’s Carnivores and Communities Program (CACP) in southern Alberta which started in 2009. Adapted from Morehouse et al. (2020).45

Introduction

Grizzly bears in Canada are designated nationally as ‘Special Concern’ by the Canadian Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the federal Species at Risk Act. This designation was made due to the bear’s North American population decline over the past 150 years, its sensitivity to human disturbance and human-caused mortality, poor population data across its range, a few local population declines, and extensive fragmentation in the southern portion of its Canadian range (COSEWIC 2012). However, there is evidence of a stable population overall across their distribution in Canada (COSEWIC 2012). There are approximately 15,000 grizzly bears in British Columbia (B.C.), 700 in Alberta, and 13,000 north of the 60th parallel in the Yukon, Northwest Territories, and Nunavut (Fig. 1). While bears live within generally large robust populations in northern portions of the provinces, their populations along the periphery of their distribution in Alberta and along the Canada-U.S. border have varying levels of conservation concern (McLellan 1998). This concern is dominated by fragmentation creating smaller populations, conflict related mortality on their periphery in the human-settled valleys of this mountainous landscape, and by backcountry mortalities related to motorized access. In contrast to the grizzly bear conservation status in the lower-48 States where their threatened status under the federal Endangered Species Act affords them significant protection and resources for conservation management, the circumstances within Canada have not resulted in a similar level of conservation concern for grizzly bears. Thus, the overall conservation management is considerably less. Also, grizzly bear management is the realm of the Provinces. Grizzly bear conservation and management within B.C. is guided by the Wildlife Act and B.C.’s Conservation Strategy. Similarly, in Alberta, a provincial grizzly bear recovery plan provides the basis for bear conservation and management (Alberta Environment and Parks 2016).

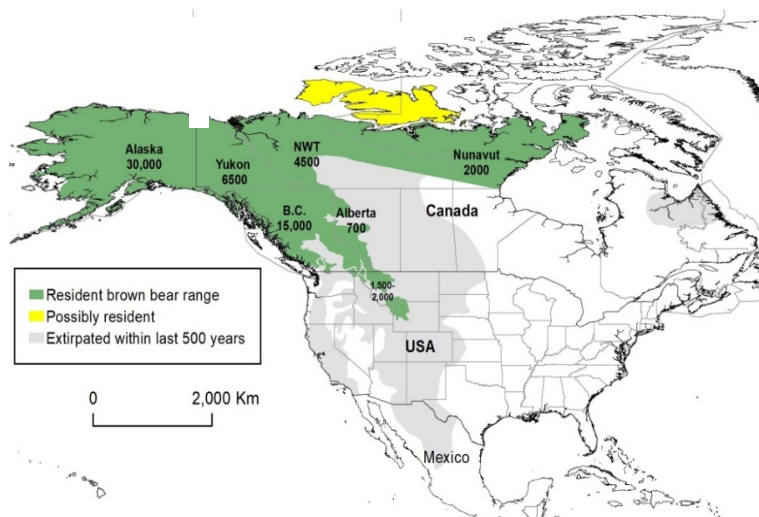


Figure 1: Grizzly bear distribution in western North America with abundance estimates. Adapted from Proctor et al. (2021a).

The main benefit of Canadian grizzly bears to those in the lower-48 States is the provision of genetic and demographic connectivity. Here we speak of connectivity in terms of movements between areas that are accompanied by breeding. Genetic connectivity resists losses of genetic diversity that usually occur in small, isolated populations and is more easily mediated by more vagile males (Proctor *et al.* 2005). Demographic connectivity offers a ‘rescue’ effect for small, isolated populations that may lose females (and reproductive capacity) through stochastic (chance) events (e.g., disease) or through more deterministic process (e.g., excessive human-caused mortality on the periphery of small populations) (Proctor *et al.* 2012, Lamb *et al.* 2016). For example, the international South Selkirk population had been totally isolated for decades (Proctor *et al.* 2005, 2012), but is currently experiencing increased connectivity and has been for the past decade (Proctor *et al.* 2018). This population’s best opportunity for genetic and demographic connectivity from a larger healthier population occurs with the south Purcell Mountains of southern B.C. across the Creston Valley and B.C. Highway 3A (just north of Bonners Ferry, Id). This same Purcell Mountain grizzly population is the nearest population to reconnect the international Yahk/Yaak population. In fact, males have remained partially connected across B.C Highway 3 into the Yahk/Yaak population, mediating genetic connectivity, but demographic connectivity has been lacking (Proctor *et al.* 2005, 2012).

Additionally, B.C. and Alberta combined have many more bears than are in the lower-48 States, particularly B.C. (Fig. 1), which until recently, allowed a decades-long sustainable grizzly bear hunt (McLellan *et al.* 2017a). In 2017, the B.C. grizzly bear hunt was halted on ethical grounds and public opposition, not conservation concern. This fundamental difference between bear populations in B.C and the lower-48 States has resulted in a difference in intensity of conservation management between the two jurisdictions. However, many of the conservation challenges present in the lower-48 States are also present in Canada, particularly for bear populations along the Canada-US border. Fragmentation from human settlement patterns, human-caused mortality, and traffic on major highways has created small, fragmented or isolated threatened populations in the lower-48 States (i.e., the South Selkirk, Yaak, and Cabinets populations, Proctor *et al.* 2012). Canadian Highway 3, just north of the US-Canada border, and its associated settlement is responsible for much of the fragmentation of Canadian bear populations and separates these trans-border populations from the larger Canadian grizzly bear populations to the north (Proctor *et al.* 2005). In that regard, there has been much research and conservation effort to reverse this fragmentation within Canada and some measure of success to date. A large network of government agencies, Environmental Non-government Organizations (ENGOS), and public interest groups from both countries are beginning to work cooperatively to solve this problem.

The other area of enduring conservation management in Canada is the challenge the provinces have with motorized access management, an important tool in grizzly bear conservation management (Proctor *et al.* 2020). While there have been local motorized access management plans initiated, some successfully, they have been a challenge to implement more broadly.

Here we review the research, management, conservation progress, and status of grizzly bear populations in British Columbia and Alberta, Canada with a focus on those just north of the 49th parallel. We briefly provide an overview of bear populations further north.

British Columbia Overview

Most (~80%) of British Columbia (B.C.) is grizzly bear habitat; grizzly bears were extirpated due to human settlement associated with excessive human-caused mortality over the past century from the lower mainland around the metropolis of Vancouver, south-central Okanagan valley, and a small corner in northeastern B.C. (Fig. 1). Going north in B.C, the influence of humans decreases, and grizzly bears flourish. B.C. covers ~950,000 km² and grizzly bears occupy ~750,000 km². In contrast, in the lower-48 States, grizzly bears occupy a much smaller area of approximately 55,000 km². The ecology of B.C. is incredibly varied from moist mountainous forests in the east, to the semi-desert Okanagan in the dry central interior, to very wet coastal mountain forests in the west; grizzly bear habitat productivity also varies over this range (Mowat *et al.* 2013).

Grizzly bears were intentionally killed in B.C. during European settlement into the early 1900s' (McLellan 1998), and hunting went unregulated until the late 1960s when spring and fall hunts were initiated. In the mid-1970s, a Limited Entry Hunt (LEH) was instigated in the southern portion of the province (Peek *et al.* 2003). B.C. adopted a grizzly bear Conservation Strategy in 1995 (B.C. Conservation Strategy 1995), and in 1996 the LEH was extended to the entire province with limits on the numbers of females taken (Peek *et al.* 2003). With a few localized exceptions, the hunt was then sustainable for decades after the LEH was applied (McLellan *et al.* 2017a, Hatter *et al.* 2018), although concerns have been raised (Artelle *et al.* 2013). The biggest challenges in managing for an accurate sustainable mortality rate, were the inability to estimate the grizzly bear population across the province accurately and to account for unreported mortalities. After the DNA survey method was developed in 1995 (Proctor 1995, Woods *et al.* 1999), reliable population estimates were carried out over portions of the province and unreported mortality was estimated from telemetry research and hunting quotas were assessed and adjusted accordingly. In 2017, the legal hunt was halted due to public opposition, although First Nations are allowed to hunt for food, social, or ceremonial reasons (<https://news.gov.bc.ca/releases/2017FLNR0372-002065>). It is also legal to kill a grizzly bear in defense of life or property.

The current estimated grizzly bear population in B.C. is ~15,000, and bear densities vary from <10 to >400 bears/1,000 km² (Mowat *et al.* 2013). Provincially, grizzly bears are ranked as 'Special Concern' by the B.C. Conservation Data Center and federally under the Species at Risk Act (COSEWIC 2012, SARA 2018). While grizzly bears are internationally designated as 'Least Concern' by the IUCN Red List of Threatened Species, four populations within B.C. were designated as 'Threatened', 3 of which span the Canada-U.S. border (North Cascades-Critically Endangered, South Selkirk-Vulnerable, and the Yahk/Yaak-Endangered, McLellan *et al.* 2017b).

B.C.'s estimated 15,000 grizzly bears (B.C. Min. FLNRORD 2020) are managed through 55 Grizzly Bear Population Units (GBPU), which were formed with natural and anthropogenic boundaries in mind (Fig. 2a). Originally GBPUs were ranked as 'threatened', 'viable' or 'extirpated' based on the perceived relationship between their current bear numbers and their potential 'carrying capacity' (Austin and Hamilton 2004). This system was replaced recently by a more measurable, objective method based on principles developed by the IUCN and implemented by a Nature Serve-based system of conservation ranking (Fig. 2a, Morgan *et al.* 2020). Current rankings span 5 categories M1 – M5 with the highest level of conservation

concern in units labelled M1. The IUCN and Nature Serve labels are primarily designed to assess extinction risk, but because most GBPU's in B.C. are jurisdictional units that are often inter-connected with neighbouring units and not biologically isolated populations, their extinction risk is generally very low. For this reason, the B.C. government refers to their status with relative descriptors of 'conservation concern' M1 – M5. This applies to all of B.C.'s GBPU's except a few that are biologically isolated or intensely fragmented and are separately designated by the IUCN Red List Assessment process as mentioned above (McLellan *et al.* 2017b).

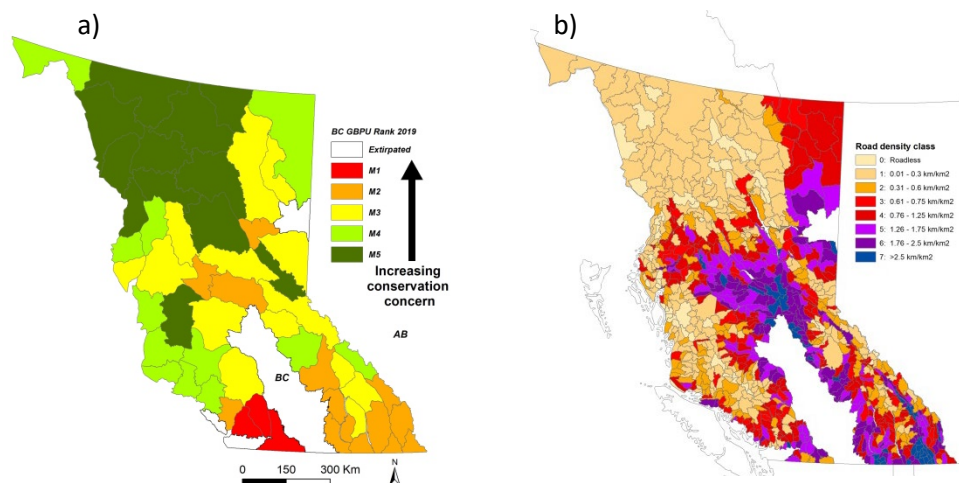


Figure 2: a) Grizzly Bear Population Units across B.C. ranked for conservation status using the Nature Serve threats assessment protocols (Morgan *et al.* 2020) and, **b)** road density by landscape unit across British Columbia (Adapted from Proctor *et al.* 2020).

The 1995 Grizzly Bear Conservation Strategy declared that B.C.'s grizzly bears would be managed to “maintain in perpetuity the diversity and abundance of Grizzly bears and the ecosystems on which they depend throughout British Columbia” and “to improve the management of Grizzly bears and their interactions with humans.” In 2016, the B.C. Ministries of Environment and Climate Change Strategy and Forests, Lands, and Natural Resource Operations and Rural Development (FLNRORD) updated that commitment with 3 objectives:

1. Ensure Grizzly bear populations are sustainable, including managing for genetic and demographic linkage;
2. Continue to manage lands and resources for the provision of sustainable Grizzly bear viewing opportunities; and
3. Where appropriate, restore the productivity, connectivity, abundance and distribution of Grizzly bears and their habitats.

A Provincial Grizzly Bear Management Plan has been developed and is in review as of January 2021 in response to a report tabled by the B.C Auditor General in 2017 (OAG 2017, Garth Mowat, B.C Carnivore specialist, pers. comm.). The primary conservation concerns for grizzly bears in B.C. include human-bear conflicts, anthropogenic habitat alteration, and loss of connectivity.

Human-bear conflicts are responded to by the B.C. Conservation Officer Service (COS), though this is a small part of a B.C. Conservation Officer's duties. The B.C. COS is responsible for enforcing a wide variety of wildlife related laws and regulations including natural resource compliance and enforcement, hunting regulations, human safety, property damage and conflict response relative to all wildlife, including grizzly bears. The B.C. COS has detailed bear conflict response protocols that apply a decision tree based on the type of conflict, the history of the bear, threat level to people and property, and other factors (B.C. COS 2020a and b). Responses to human-grizzly bear conflicts vary and can include education and information sharing, attractant management improvements and the promotion of electric fencing through ENGO programs, translocation of grizzly bears within or (more rarely) outside their home range, or euthanasia. On average, 44% of grizzly bears involved in conflicts responded to by the B.C. COS are killed by Conservation Officers; that number rises to 61% when private citizen kills are included (B.C. government data).

To help prevent human-grizzly bear conflicts, British Columbia has a province-wide government-sanctioned WildSafe B.C. program. This program is collaboratively delivered and includes education and community-based solutions. The program evolved from the provincial Bear Aware program, is administered by the B.C. Conservation Foundation, and works cooperatively with the Ministry of Environment's Bear Smart Program and the B.C. COS. Community based 'specialists' live and work within sponsoring communities to help develop place-based conflict mitigation options; the cost of these positions is shared between WildSafe and the sponsoring communities.

Motorized access management is known to be an important habitat management tool for grizzly bear conservation (Mace *et al.* 1996, Schwartz *et al.* 2010, Boulanger and Stenhouse 2014, Lamb *et al.* 2018, Proctor *et al.* 2020, 2021b). However, its use in B.C has been limited and no province-wide or GBPU-specific targets exist (Proctor *et al.* 2019, Morgan *et al.* 2020, Fig. 2b). Exceptions to this pattern are in the southeast corner of B.C. in the Flathead and South Rockies GBPU just north of the U.S. Glacier National Park, in southwest B.C. with a local initiative, in the Granby-Kettle GBPU to the west of the South Selkirks (Lamb *et al.* 2018) and in the privately owned Nature Conservancy of Canada Darkwoods lands within the South Selkirk GBPU (Proctor *et al.* 2018, 2021b).

Finally, the loss of connectivity is an additional conservation challenge for southern B.C.'s bear populations. B.C. Highway 3 runs east-west and bisects several GBPU in southern B.C just north of the Canada-U.S. border (Fig. 3). The north-south mountain ranges create a series of valleys that act as transportation and settlement corridors in the region. The combination of the fragmentation of B.C. Highway 3 and the north-south settled valleys have left a series of isolated or partially isolated sub-populations across the region, several of which are international sub-populations that span the Canada-U.S. border (Fig. 3). Varying amounts of conservation management are being applied to reverse some of this fragmentation as discussed in the GBPU summaries that follow.

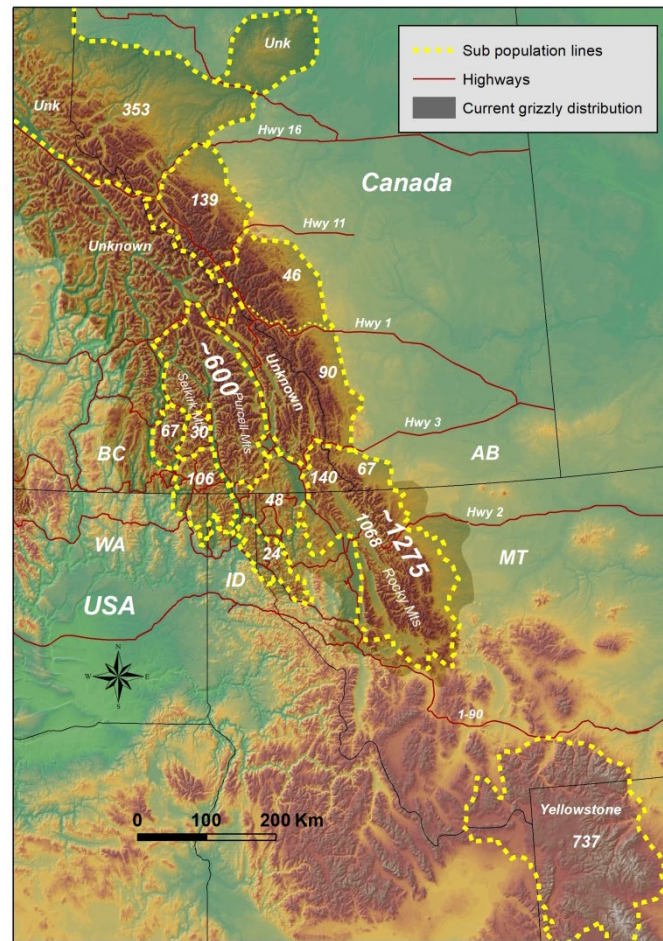


Figure 3: Fragmentation of grizzly bears, in the trans-border region spanning the Canada-U.S. border. Yellow dotted lines represent primarily female fragmentation, but with reduced male connectivity as well. Numbers are population estimates within these ‘biological’ subpopulations (adapted from Proctor et al. 2012).

British Columbia – U.S. border Grizzly Bear Population Units

There are 6 B.C. Grizzly Bear Population Units (GBPU) along the U.S. border that are immediately relevant to grizzly bear recovery ones in the lower-48 States (Fig. 4). Here we review their status, research, conservation efforts, and relevance to grizzly bears in the lower 48 states.

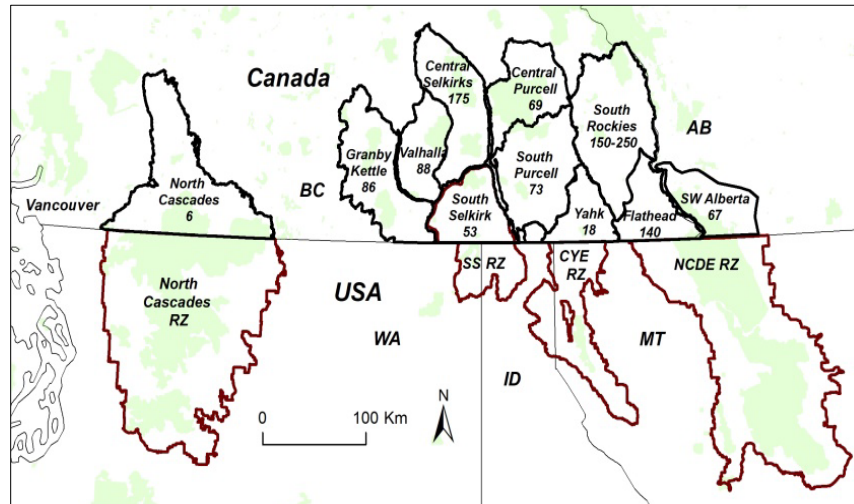


Figure 4: Grizzly Bear Population Units along the Canada-U.S. border in southern British Columbia, their estimated population size, and adjacent U.S. Recovery zones (B.C. Government 2020, Proctor *et al.* 2021b).

North Cascades

The North Cascade GBPU within Canada, up against the heavily human-populated lower mainland of B.C.'s southwest, is directly north of the U.S. North Cascades Recovery Zone and is estimated to have 6 bears within its ~9,800 km² area; however, this estimate is not backed up by reliable research (Fig. 5, B.C. FLNRORD 2020). Between 1998 and 2003 several efforts were made to survey this population (DNA sampling, live trapping effort, aerial survey for a helicopter darting attempt,) with very little results beyond one DNA sample and few sightings that included a female with offspring (North Cascades Grizzly Bear Recovery Team 2004, McLellan *et al.* 2017b). This unit is designated as M1, the highest level of conservation concern, according to B.C.'s conservation ranking assessment (Fig. 2a, Morgan *et al.* 2020). Approximately 20% of the GBPU is protected, (North Cascades Grizzly Bear Recovery Team 2004) and road densities vary across the GPBU and outside of the large, protected areas on the southern border; they range from 0.76 to 2.5 km/km² (Fig. 6).

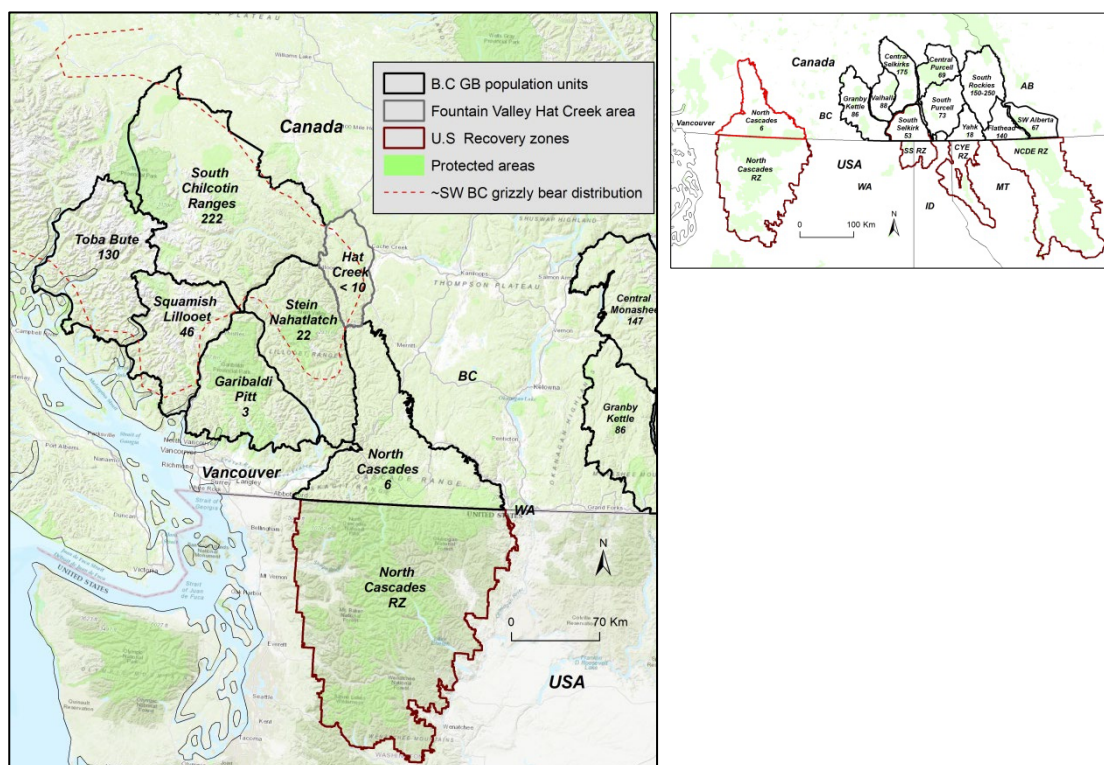


Figure 5: North Cascades region including the neighbouring Grizzly Bear Population Units to the northwest. The red dotted line is a data-based approximation of the grizzly bear distribution north of that line (Apps et al. 2014). The distribution in the North Cascades is unknown.

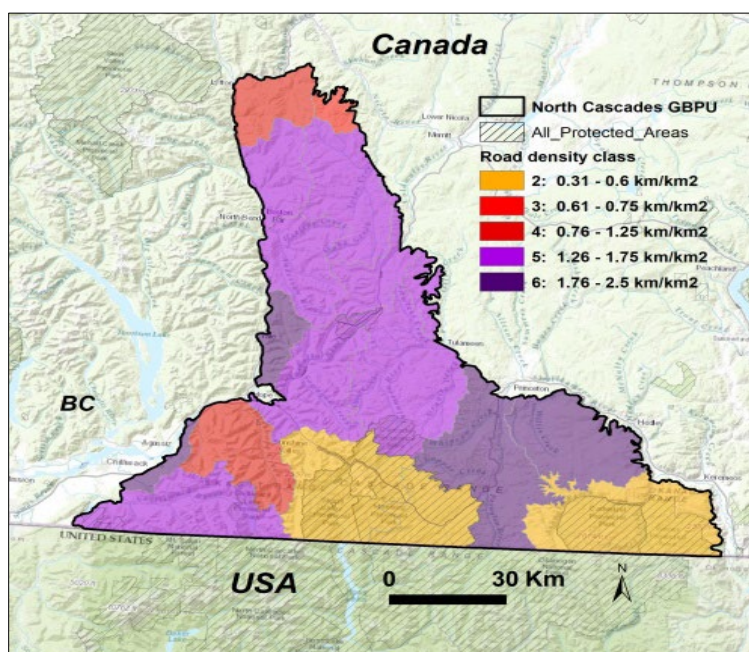


Figure 6: Road density classes in the North Cascade Grizzly Bear Population Unit of southwestern B.C.

The B.C. government developed a well-considered North Cascades Recovery Plan (North Cascades Grizzly Bear Recovery Team 2004) to recover and /or recolonize this population. Stated objectives included:

- conserve and enhance linkages (with the Stein Nahatlatch GBPU),
- augment the population genetically through the introductions of animals from other populations,
- manage habitat through motorized access controls if necessary,
- minimize human-bear conflicts,
- initiate recreation trail planning,
- minimize human-caused mortality of grizzly bears,
- cooperate with the U.S. authorities on recovery efforts, and
- monitor recovery progress.

The plan was never implemented due to the public's concern for translocating bears into the area (OAG 2017). No outreach effort was undertaken to alleviate those concerns (OAG 2017). Recently, however, the Okanagan Nation Alliance has undertaken efforts to update this Recovery Plan in collaboration with other First Nations, ENGOS and the B.C. government.

The North Cascade 'population' is totally isolated from adjacent populations (North Cascades Grizzly Bear Recovery Team 2004). Connectivity from the east is unlikely as the nearest population is over 100 km across the heavily human-settled Okanagan Valley (North Cascades Grizzly Bear Recovery Team 2004, McLellan *et al.* 2017b). To assess connectivity from the northwest it is useful to consider the GBPU in that area (Fig. 5). The immediately adjacent GBPU is the recovering Stein-Nahatlatch, itself ranked M1, and estimated to have a very low density of bears (2.9 bears/1,000km², or 22 grizzlies, B.C. FLNRORD 2020, Morgan *et al.* 2020, Apps *et al.* 2008, 2014) and very low genetic diversity estimated through genetic heterozygosity ($H_E = 0.51$, Apps *et al.* 2014). Both the North Cascades and Stein-Nahatlatch GBPU are designated as 'Critically Endangered' small, isolated populations by the IUCN Red List (McLellan *et al.* 2017b). While the adjacent Stein-Nahatlatch GBPU is within the dispersal distance of both male and female grizzly bears, only the northern half is occupied by grizzly bears (Fig. 5, Apps *et al.* 2008, 2014). The fracture that separates the North Cascades and the Stein-Nahatlatch is significant and consists of the large Fraser River valley and canyon, the heavily travelled Trans-Canada Highway, two railways, human settlements and other developments.

The Stein-Nahatlatch GBPU has been completely isolated until recently when it has experienced a few male exchanges with the South Chilcotin Ranges GBPU to the northwest, but no female interchange has been documented (McLellan *et al.* 2017b). The fracture separating the Stein-Nahatlatch from the South Chilcotin Ranges is of minimal intensity with a low volume railroad and highway, sporadic rural settlement, and several lakes (McLellan *et al.* 2017b).

The South Chilcotin Ranges GBPU is the closest larger healthier population of grizzly bears (222 bears, FLNRORD 2020), known to also be increasing (McLellan *et al.* 2019), that would be a source of genetic and demographic connectivity to the Stein-Nahatlatch and ultimately the North Cascades. For natural connectivity to occur between the South Chilcotin Ranges through the

Stein-Nahatlatch and into the North Cascade GBPU, a considerable amount of population and connectivity recovery needs to occur. Briefly, the South Chilcotin Ranges GBPU would need to continue its recovery trajectory (a reasonable assumption given current efforts and attention), and the Stein-Nahatlatch would have to do the same. That, however, is a bigger challenge because there are so few bears with limited distribution in this unit currently (McLellan *et al.* 2019). Beyond these improvements, the considerable fracture separating the Stein-Nahatlatch and the North Cascades created by the large highway, two railroads, large Fraser River, and human settlements would have to be overcome through extensive conservation management.

Considering the low density, limited distribution, fragmentation of the Stein Nahatlatch bears with the adjacent South Chilcotin Ranges GBPU to the north, and the severity of the fracture separating the Stein-Nahatlatch from the North Cascades, genetic or demographic connectivity to the North Cascades is unlikely in the near future. However, there are efforts in research and conservation management ongoing in the region that provide long-term potential for connectivity and recovery of the Stein-Nahatlatch and eventually the North Cascade GBPUs.

A considerable amount of conservation-oriented research has been occurring in the region to the northwest of the North Cascade GBPU (Apps *et al.* 2014, McLellan and McLellan 2015, McLellan *et al.* 2019), including work revealing population-level fragmentation (Apps *et al.* 2014) and identification of corridors across the valley fragmenting the Stein-Nahatlatch from the South Chilcotin Ranges GBPU (Fig. 5, McLellan 2018). A consortium of ENGOs, First Nations, and the B.C. government have been working on implementing conservation solutions similar to those shown to be working in the South Selkirk GBPU (see below, Proctor *et al.* 2018), including conflict reduction strategies, purchase of private connectivity properties by a land trust, and initial motorized access management applications. A population augmentation program for the Stein-Nahatlatch GBPU is being planned as a cooperative effort between the B.C. Government and the local St'at'imc, NlaKa'pamux, and Simpcw First Nations (<https://www.conservationnw.org/our-work/habitat/coast-range-to-cascades/>). The source of non-salmon-dependent bears would likely come from healthy populations in central B.C. Plans are to continue this effort for 5 years and assess progress and success.

In addition to these GBPUs is the small Hat Creek area (~1,400 km²) to the east of the Stein Nahatlatch GBPU (Fig. 5) that possibly contains reproductive females (McLellan *et al.* 2017b). Also adjacent to the Stein-Nahatlatch GBPU is the Garibaldi Pitt GBPU which is possibly close to being functionally extirpated with an estimated 3 bears (FLNRORD 2020).

In summary, attaining natural or human-assisted genetic or demographic connectivity into the North Cascade GBPU will be a challenge that currently is not being considered as a management priority by the B.C. government (OAG 2017), but is within the long-term objectives of local First Nations and the aforementioned Coast to Cascades Grizzly Bear Initiative. Therefore, this unit is not considered a realistic source of bears to recolonize the U.S. North Cascades in the near future. However, First Nations reinvigoration of recovery plans for both the North Cascades and the Stein-Nahatlatch GBPUs in cooperation with the Coast to Cascades Grizzly Bear Initiative and the B.C government provides some hope for conservation progress in the region and should be of interest to authorities within the U.S. with interest in recovery of the North Cascades international population.

Granby-Kettle GBPU

The next GBPU in the trans-border area is the Granby-Kettle unit (Fig. 7), east of the Okanagan Valley from which grizzly bears are extirpated. This unit is designated as M2, high conservation concern, according to B.C.'s conservation ranking assessment (Fig. 2a, Morgan *et al.* 2020) suggesting that it is in need of conservation attention. Grizzly bears in the unit have not been legally hunted since 1995. The biggest threats to bears in this unit are the extensive and expanding forestry road network and its associated high ungulate hunter density and unreported mortalities (Morgan *et al.* 2020), although some recent progress has been made in motorized access management. There is limited human settlement or agriculture in the southern portion of this GBPU (black dots in Fig. 7).

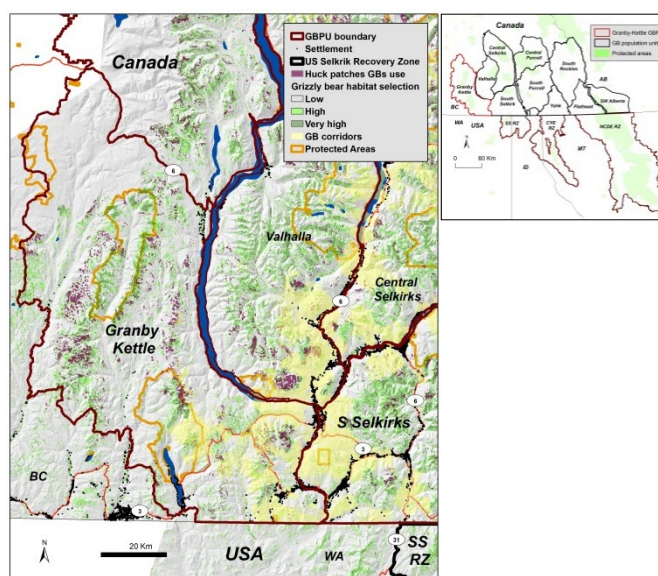


Figure 7: Granby-Kettle Grizzly Bear Population Unit along the Canada-U.S. border immediately northwest of the U.S. South Selkirk Recovery Zone. Habitat selection estimated by resource selection functions (green), grizzly corridors, (yellow), and huckleberry patches (purple) are shown (Proctor *et al.* 2015, 2021b).

A recent DNA-based population survey estimated 87 (95% CI 66-108) grizzly bears (Lamb *et al.* 2018) and represents an increase for this unit over an estimated 38 bears from a similar DNA survey in 1997 (Lamb *et al.* 2018). Between 1985 and 2001, 3 provincial parks were created in this unit encompassing 14% of the GBPU. In addition, two motorized access management areas (5% of unit area) were created to benefit grizzly bear recovery and other conservation goals. Lamb *et al.* (2018) estimated that the parks and motorized access management area helped increase the bear density by 27% and that habitats with road densities $< 0.6 \text{ km/km}^2$ had 3 times higher grizzly bears densities than habitats with road density $> 0.6 \text{ km/km}^2$. Even with these efforts, the open road density in this unit is 1.64 km/km^2 , short of a stated goal of 0.6 km/km^2 (B.C. Government Action Regulation 2004). The closest example of a GBPU-wide access management plan in B.C. occurred in this unit in 2010 when a government order was drafted to include a road density target, but it was only a recommendation in the final order. It was later determined by the B.C. Forest Practices Board that these targets were not being met in a

significant number of areas primarily because they were not legally binding. This story is detailed in the Office of the B.C. Auditor General Report (OAG 2017).

The Granby-Kettle GBPU is bisected by B.C. Highway 3 and the degree of fragmentation it causes has not been researched. Regionally, fragmentation is mediated mainly by settlement and mortality patterns and secondarily by traffic along Highway 3 (Proctor *et al.* 2012, Lamb *et al.* 2016). There are extensive sections along B.C. Highway 3 across this unit with no-to-minimal human settlement, so extrapolating the results of Proctor *et al.* (2012), it is likely that grizzly bear connectivity occurs across this highway to some degree as is the case with the unsettled Highway 3 that bisects the South Selkirk GBPU (see below).

While no direct habitat quality or telemetry-based research has occurred in the Granby-Kettle unit, Proctor *et al.* (2015) extrapolated their extensively evaluated resource selection function habitat model and grizzly bear corridor predictions into much of this unit (Fig. 7). Further, Proctor *et al.* (2021) applied their huckleberry patch ‘important-for-grizzly-bears’ model into this unit after satisfactory local field evaluation (Fig. 7). Combined with the density surface and road density analyses (Lamb *et al.* 2018) and the Proctor *et al.* (2015, 2021b) efforts, enough preliminary data exists for this unit to implement targeted conservation management such as the one attempted by the provincial government in 2010 (described above) and expand access management to other areas within this GBPU as they have done in portions of the unit (Proctor *et al.* 2020, 2021b).

In summary, the Granby-Kettle GBPU shares a 35 km border with the western edge of the Canadian South Selkirk GBPU (Fig. 7). The areas near this border within each GBPU contain a lower density of grizzly bears relative to other portions of the GBPUs and B.C. Highways 22 and 3B and their associated human settlement likely provide a degree of fragmentation between these two GBPUs. As such, the Granby-Kettle GBPU represents only minimal potential for grizzly bear connectivity with the South Selkirks. Likely a better potential exists for bears within the Granby-Kettle to be a source for bears into adjacent areas in northern Washington, although no known population exists there now.

South Selkirk GBPU

The Canadian South Selkirk GBPU is directly north of the U.S. South Selkirk and is part of the U.S. Recovery zone (USFWS 1993), although it is managed entirely by Canada (Fig. 8a). Protected areas in this GBPU include the West Arm Provincial Park (253 km²) along the northern border of the unit and the adjacent roadless Midge Creek Wildlife Management Area (created in 1998, 148 km²). These protected areas adjoin the 700 km² Nature Conservancy Canada (NCC) property, currently being managed for grizzly bear and other conservation values (Fig. 8b). This unit is designated as M2, high conservation concern, according to the B.C.’s conservation ranking assessment (Fig. 2a, Morgan *et al.* 2020) suggesting that it is in need of conservation attention. Grizzly bears in the unit have not been legally hunted since 1995. The South Selkirk subpopulation was found to be completely isolated (at the time) from adjacent subpopulations to the north, east, and west (Proctor *et al.* 2005, 2012) and the IUCN Red List assessment designated this population as ‘Vulnerable’ (McLellan *et al.* 2017b). Its small population size, complete isolation (at the time), and threats assessment suggested it should be ‘Endangered’. It was designated the lesser status of ‘Vulnerable’ because of ongoing research

and effective conservation management applied by the Trans-Border Grizzly Bear Project, the USFWS, and the B.C. Conservation Officer Service (Proctor *et al.* 2018, Kasworm *et al.* 2020a). These cumulative efforts greatly reduced its probability of extinction. More recently, Proctor *et al.* (2018) have documented increased genetic and demographic connectivity between the South Selkirk and Purcell GBPU's (see details below).

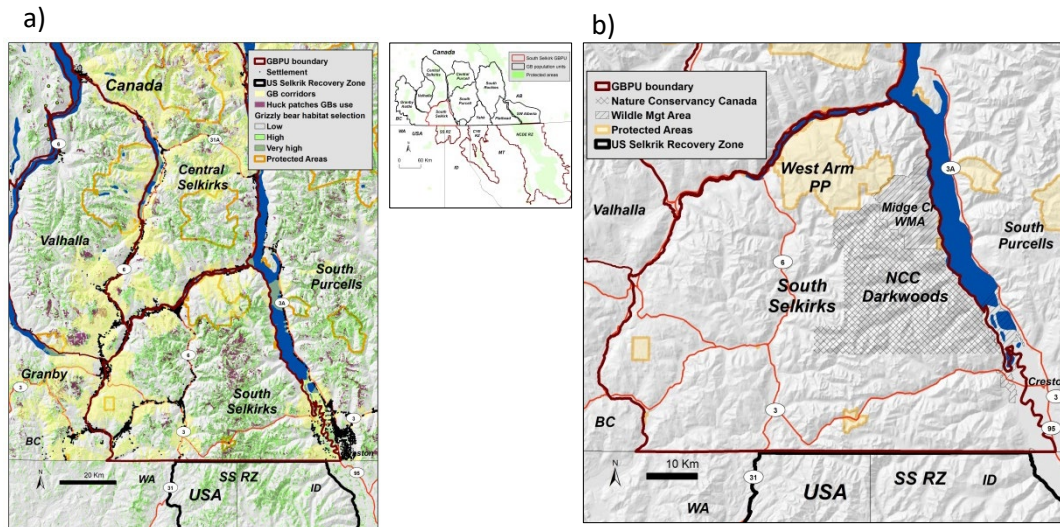


Figure 8: a) South Selkirk Grizzly Bear Population Unit along the Canada-U.S. border immediately north of the U.S. South Selkirk Recovery Zone. Habitat selection estimated by resource selection functions (green), grizzly corridors, (yellow), and huckleberry patches (purple) are show, (Proctor *et al.* 2015, 2021b), and **b)** protected lands in the South Selkirk Grizzly Bear Population Unit.

Threats to this population were (and still are to some degree), human-caused mortality primarily on the periphery, extensive forestry roads on public lands and the accompanying mortality (within Canada), and fragmentation. The Trans-border Grizzly Bear Project wrote a government sanctioned ('advice to government') Recovery Management Plan (MacHutchon and Proctor 2016). The recovery targets in this plan were patterned after targets used by the USFWS recovery of the U.S. South Selkirk Recovery Zone with several changes to reflect the Canadian program. Most of the targets were designed to be measured in a unit-wide DNA-based population survey and include, abundance, density with explanatory covariates, female distribution, distribution of reproductive females, sustainable mortality rates, sex-specific connectivity with neighboring populations and more. A DNA-based population survey is being carried out in 2020-2021, to assess conservation status using the above metrics.

There has been a significant amount of conservation-oriented grizzly bear research in the South Selkirks by the Trans-border Grizzly Bear Project, in partnership with the USFWS Libby Office. A DNA-based population survey was done in 2005, which estimated the Canadian South Selkirk unit to have 58 (95% CI 50-70) bears (Proctor *et al.* 2007). A re-analysis of the same data using the more recent Spatial Explicit Capture Recapture (SECR) methodology estimated 53 (95% CI 41-68 Proctor *et al.* 2021b). Forty grizzly bears were collared with GPS telemetry between 2007-

2017, the data of which were used to estimate habitat quality, important hyperphagia food patches, connectivity corridors, female reproduction, sources and rates of mortality, conflict management, and more (Fig. 8a). Proctor *et al.* (2021b) identified and mapped huckleberry patches important for grizzly bears using GPS telemetry to find the patches and model their distribution (Fig. 8a). Interestingly, they found that huckleberry patches in areas of high road density and low proportion secure habitat were not translating into grizzly bear densities. For example, the average open road density in the unit is 1.1 km/km² while the open road density in the Nature Conservancy Canada's land is 0.3 km/km² attained through an access management program on their lands. The average bear density for the entire unit is 13.1 grizzly bears/1,000 km², while the grizzly density in the NCC Darkwoods property is 33 grizzly bears/1,000 km². This higher bear density in the NCC Darkwoods lands is a result of the combination of a low road density and a higher huckleberry patch density (Fig. 9a and b. Proctor *et al.* 2018, 2021). Proctor *et al.* (2021b) found that grizzly bear densities were 2.5 times higher in habitats < 0.6 km/km² open road density, relative to habitats > 0.6 km/km².

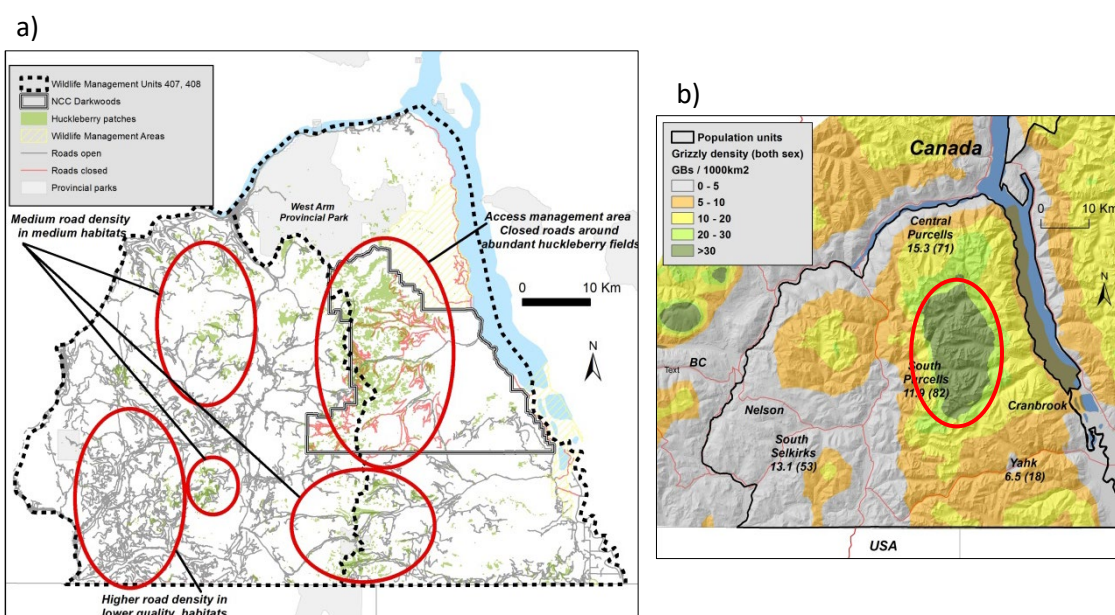


Figure 9: a) An example of resource road management on Nature Conservancy of Canada lands in the South Selkirk Mountains as a mitigation for backcountry mortality and to increase habitat effectiveness (adapted from Proctor *et al.* 2018). Public access was controlled around good huckleberry patches, and this resulted in increased female habitat use, density, and realized reproductive output (fitness). Adapted from Proctor *et al.* (2018), and **b)** Grizzly bear density in the South Selkirk Grizzly Bear Population Unit. Red oval indicated are of highest density that corresponds to the upper right red oval in a) where access management has been applied by the Nature Conservancy Canada and huckleberry patch density is high (Proctor *et al.* 2021b).

Road density and the proportion of secure habitat (> 500 m from an open road) varies across the South Selkirk GBPU. The Trans-border Grizzly Bear Project subdivided this unit (and other GBPU in the Purcell Mountains) into 'Bear Management Units' (BMUs) for the purpose of

understanding the spatial variability of these access metrics (Fig. 10a and b). Note these BMUs are not legal entities, but are used for conservation planning. This exercise exposes local areas within these units that would benefit from access management as recommended in Proctor *et al.* (2020).

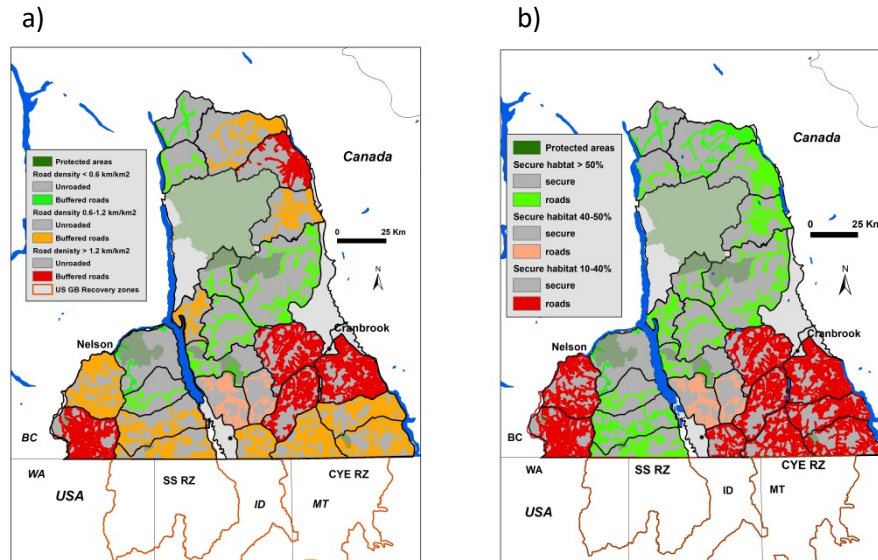


Figure 10: a) Road density categories within ‘Bear Management Units’ (created by the Trans-border Grizzly Bear Project to help understand road access, these are not legal entities) across the South Selkirk, Yahk, South Purcell and Central Purcell Grizzly Bear Population Units in southeastern B.C. Adapted from MacHutchon and Proctor 2016). Colors are open roads buffered by 500 m, and **b)** Percentage of secure habitat (> 500m from an open road) across the same Bear Management Units.

The fragmentation that originally created this previously isolated population was primarily from B.C. Highway 3A that runs north of Creston and west to Nelson along Kootenay Lake. B.C. Highway 3 cuts east-west through the South Selkirk unit but does not significantly fragment grizzly bears as there is virtually no human settlement along the highway as it crosses much of the unit (Proctor *et al.* 2012).

Proctor *et al.* (2015) identified the best options for establishing a grizzly bear corridor to a larger population to be across the north end of the Creston Valley into the south Purcell Mountains (Figs. 11a and b). The Trans-border Grizzly Bear Project has implemented a suite of connectivity conservation and management actions over the past decade (Proctor *et al.* 2018). Activities included a cost-share electric fencing program, other attractant management activities, a private land purchase program (i.e., purchasing lands or conservation easements within identified corridors through the NCC and other land trust ENGOs, Fig. 11b), and a non-lethal conflict response program in conjunction with the B.C. COS - patterned after the Montana Fish Wildlife & Parks bear management program. These activities have resulted in a decrease in human-caused mortality in the South Selkirk GBPU relative to the previous decade (Figs. 12a, b, Proctor *et al.* 2018). Conversely, mortality trends in the adjacent population unit to the east that did not receive these management activities have continued to increase (Fig. 12c).

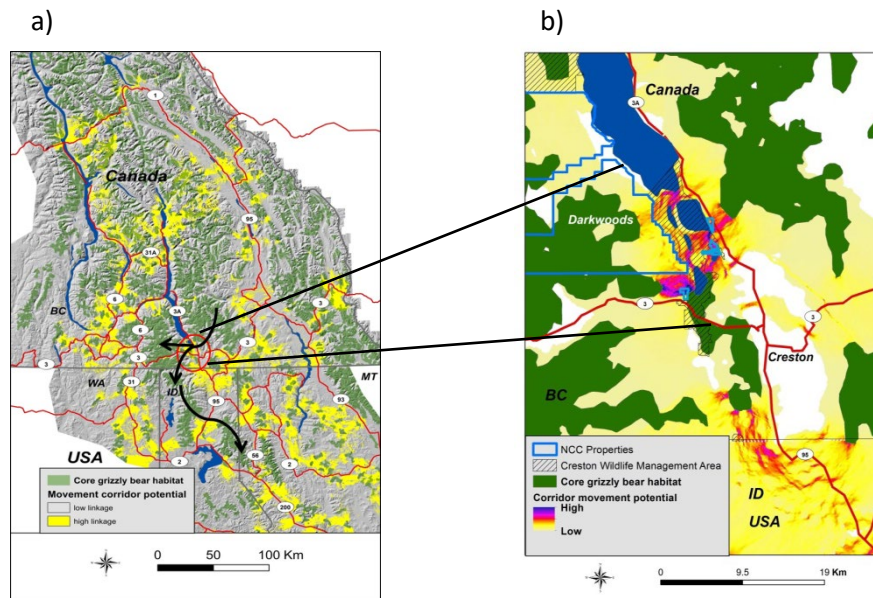


Figure 11: a) Research-identified grizzly bear corridors in the trans-border Canada-U.S. region (Yellow) connecting higher quality habitat patches (green). The black arrows represent the best corridor option connecting the U.S. South Selkirk grizzly bears to the larger Canadian population in the Purcell Mountains through the Creston Valley (red circle) and **b)** Close up of the Creston Valley showing the best linkage habitat (red flames) in relation to connectivity land purchases by the Nature Conservancy Canada (NCC, blue polygons, adapted from Proctor et al. 2018).

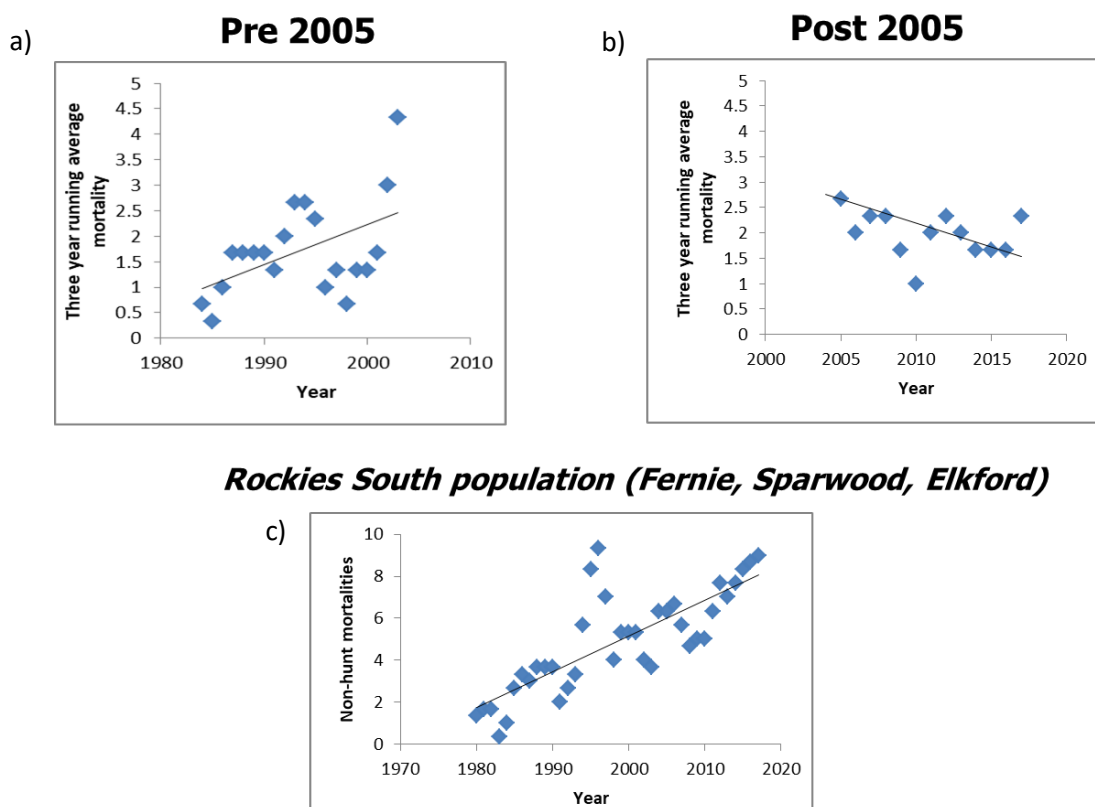


Figure 12: **a)** Conflict-related human-caused grizzly bear mortality in the Canadian South Selkirk Grizzly Bear Population Unit prior to the instigation of connectivity mortality reduction management actions, **b)** mortalities after the initiation of mortality reduction management, and **c)** human-caused mortality in the adjacent valley to the east where connectivity mortality reduction management was not applied with the same intensity as in the Creston Valley area (adapted from Proctor *et al.* 2018).

The South Purcell population unit is the southern tip of a much larger healthier population of approximately 600 grizzly bears (Proctor *et al.* 2012). The Creston Valley grizzly bear corridor is the best option for reconnecting the U.S. South Selkirk population to a large healthy population north of B.C. Highways 3 and 3A (Figs. 7a and b). Recent research has found increasing levels of genetic and demographic connectivity to be occurring between grizzly bears in South Selkirk and South Purcell Mountains as a result of the above-mentioned conservation management actions (Figs. 13 and 14, Proctor *et al.* 2018). Proctor *et al.* (2018) documented an increase in heterozygosity, a measure of genetic diversity, from 0.54 to 0.57, and 13 of 15 microsatellite loci tested increased their number of alleles between 2005 and 2017. They also documented an increase in the number of female and male immigrants into the Selkirk population from the Purcell Mountains to the east (1 female prior to 2005 to 4 females by 2017, and 0 males before 2005 to 6 males by 2017 (Figs. 14a and b). They also documented movement into the South Selkirk GBPU from the South Purcell GBPU accompanied by breeding (Fig. 13, Proctor *et al.* 2018). More recently the research team identified a female immigrant into the Selkirk GBPU that bred (unpublished data).

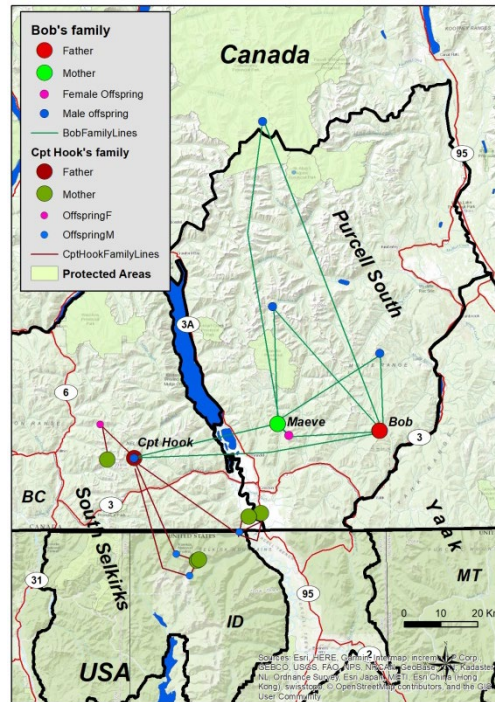


Figure 13: Example of grizzly bear (*Ursus arctos*) movement and gene flow across the Creston Valley from the South Purcell Mountains to the previously isolated South Selkirk population in the Canada-U.S. trans-border region. Example is a family pedigree where offspring all share 1 allele from each parent across 21 loci. Lines connect offspring to their parents. Dot locations represent each bear's capture or sample location. In this extended family, Bob and Maeve produced offspring Cpt. Hook who moved from the South Purcell into the South Selkirk Mountains where he mated with 5 separate females yielding six offspring (1 of the blue dots for male offspring represents 2 offspring sampled at the same location). Adapted from Proctor et al. 2018.

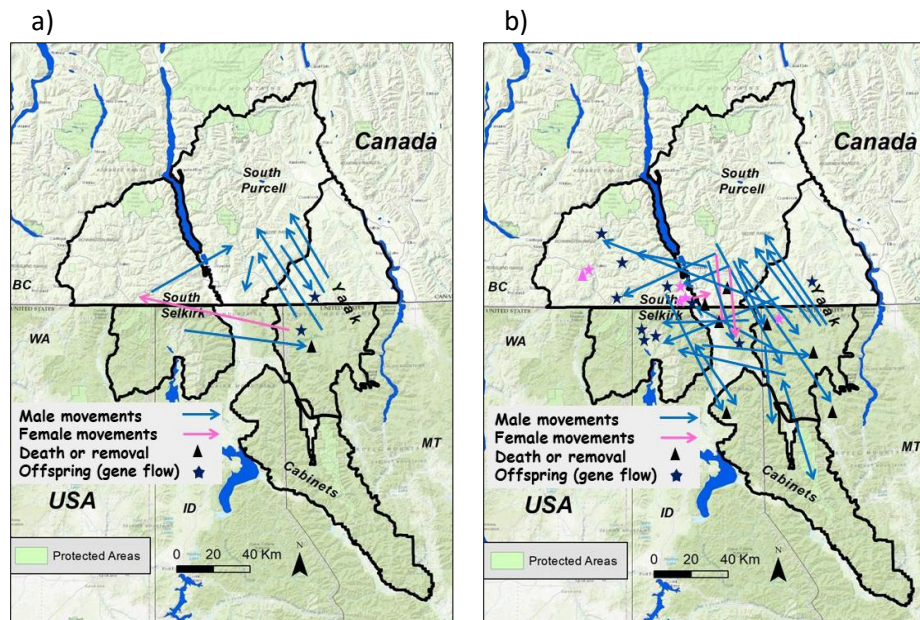


Figure 14: a) Cumulative evidence of inter-population grizzly bear (*Ursus arctos*) movements and gene flow (breeding events after movements) prior to 2006 and **b)** after mortality reduction management was applied post-2006 in the Canada-U.S. trans-border region of northwest Montana, northern Idaho, and southeast B.C (adapted from Proctor *et al.* 2018).

In summary, the Canadian South Selkirk GBPU is the most important link for the bears in the U.S. portion of the South Selkirk Recovery Zone to be connected to a larger grizzly bear population in Canada. This genetic and demographic connectivity has its best hope across the Creston Valley just north of the U.S. border north of Bonners Ferry, Idaho (Proctor *et al.* 2015). Recent and ongoing conservation efforts within Canada have measurably enhanced both genetic and demographic connectivity for the South Selkirk Recovery Zone (Proctor *et al.* 2018), however, the job is not complete. While progress in the right direction is apparent, sustained efforts are needed to make these improvements permanent and to install the management paradigms within Canadian society. This entails the B.C. Conservation Officer Service continuing its work to apply non-lethal management to appropriate conflict bears, the continuation of the privately run 50% cost-share electric fencing program, further and improved management of deadstock in the agricultural community of the Creston Valley, improved management (installed and maintained electric fences) of cherry orchards in the valley, and improved management of bear attractants on dairy farms. These solutions need to be made permanent fixtures in the way rural residents, farmers, and ranchers live and do business in the region. These have been the goals of the Trans-border Grizzly Bear Project and while they operate, there has been forward movement.

However, the Trans-border Grizzly Bear Project was not developed to be a permanent fixture on this landscape. Further, while the B.C. government has been an important partner in conservation management activities to this point in time, they are not currently prepared to be the leader of grizzly bear conservation and management into the future. Similarly, even government policies

are not permanent and are subject to changing political climates. Facilitating coexistence between bears and people in multi-use landscapes is a persistent challenge, and one that requires engagement from multiple parties. Wildlife is a public good, and as such, responsibility for both facilitating and maintaining coexistence should not fall solely on one group. As such, we look to both public and private players to continue these promising conservation efforts.

Yahk GBPU

The Canadian Yahk GBPU is directly north of the Yaak portion of the U.S. Cabinet-Yaak recovery zone. While the two areas are fully connected across the international border, the Canadian Yahk, is not a part of the U.S. Cabinet-Yaak recovery zone (Figs. 4 and 10). Provincial parks in the unit amount to approximately 1% (28 km²) of the unit (Fig. 10). This unit is designated as M2, high conservation concern, according to B.C.'s conservation ranking assessment (Fig. 2a, Morgan *et al.* 2020) suggesting that it is in need of conservation attention. Grizzly bears in the unit have not been legally hunted since 1976. The international Yahk/Yaak subpopulation was found to be primarily female fragmented from adjacent subpopulations to the north, east, and west (Proctor *et al.* 2005, 2012). The IUCN Red List assessment designated this population as 'Endangered' (McLellan *et al.* 2017b) due to its small population size and female fragmentation. It was not down listed to 'Vulnerable' because at the time, its conservation metrics were not as promising as they are today (Kasworm *et al.* 2020b). In particular, the trend estimates and connectivity metrics have improved (become positive) in recent years (Kasworm *et al.* 2020b, Proctor *et al.* 2020). These improvements reduce its probability of extinction.

Threats to this population were (and still are to some degree), human-caused mortality primarily on the periphery, extensive forestry roads and the accompanying mortality (within Canada), and fragmentation. The Trans-border Grizzly Bear Project Recovery Management Plan discussed in the South Selkirk GBPU section also covers this population unit (MacHutchon and Proctor 2016). There is a possibility of a DNA-based population survey being carried out in the near future to assess conservation status using the metrics defined by the recovery management plan.

There has been a significant amount of conservation-oriented grizzly bear research in the Yahk by the Trans-border Grizzly Bear Project, in partnership with the USFWS Libby Office. A DNA-based population survey was done in 2004-2005, which estimated the Canadian Yahk unit to have 20 bears (95% CI 16-24) (Proctor *et al.* 2007). A re-analysis of the same data using the more recent Spatial Explicit Capture Recapture (SECR) methodology estimated 18 bears (95% CI 13-25 Proctor *et al.* 2021b). Grizzly bears were fitted with GPS telemetry between 2004-2010, the data of which were used to estimate habitat quality, important hyperphagia food patches, connectivity corridors, female reproduction, sources and rates of mortality, conflict management, and more (Fig. 15). Proctor *et al.* (2021b) identified and mapped huckleberry patches-important-for-grizzly bears using their GPS telemetry to find the patches and model their distribution (Fig. 15). The average open road density in the unit is 1.6 km/km². The average bear density for the entire unit is 6.5 grizzly bears/1,000 km² and is low relative to other units in the region (Fig. 10, Proctor *et al.* 2012, B.C. Min FLNRORD 2020). The low bear density in the Canadian Yahk is likely related to the overall low huckleberry patch density and higher road density (Figs. 10 and 15, Proctor *et al.* 2021). Proctor *et al.* (2021b) estimated that there is potential for increased numbers of grizzly bears in the Yahk unit through the application of

access management. Decreasing road density to the recommended target of 0.6 km/km² has the potential to double the numbers of bears in the Canadian Yahk (Proctor *et al.* 2021b).

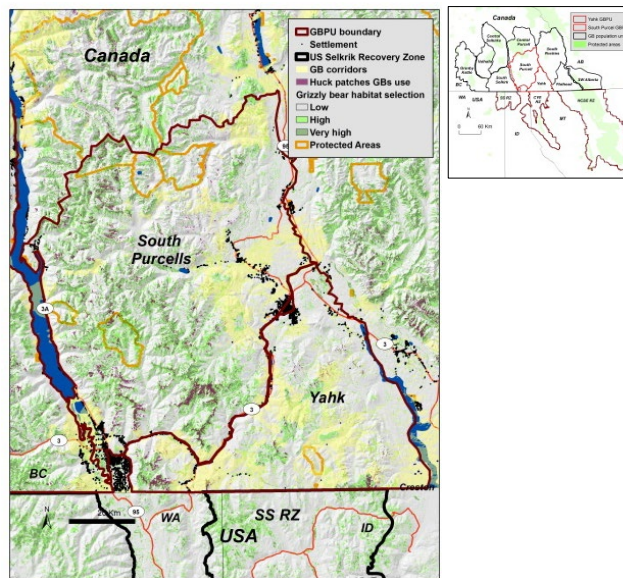


Figure 15: Yahk and South Purcell Grizzly Bear Population Units along the Canada-U.S. border immediately north of the US South Selkirk Recovery Zone. Habitat selection estimated by resource selection functions (green), grizzly corridors, (yellow), and huckleberry patches (purple) are shown (Proctor *et al.* 2015, 2021b).

The fracture creating this female fragmented population is primarily from B.C. Highway 3 that runs east - west across the Purcell Mountains. This highway and associated settlement have been shown to limit female bears and reduce male movements (Proctor *et al.* 2005, 2012). Proctor *et al.* (2015) identified the best options for establishing a grizzly bear corridor to a larger population to be across B.C. Highway 3 into the South Purcell Mountains (yellow in Fig. 15). As mentioned above for the South Selkirk GPBU, the Trans-border Grizzly Bear Project has implemented a suite of connectivity conservation management actions over the past decade. These activities have resulted in an increase in connectivity between the Yahk and the South Purcell population unit to the north (Fig. 14, Proctor *et al.* 2018). The South Purcell population unit is the southern tip of a much larger healthier population of approximately 600 grizzly bears (Proctor *et al.* 2012). The research-identified corridors are the best option for reconnecting the U.S. Yaak grizzly bear population to a large healthy population north of B.C. Highway 3 (Figs. 3 and 15).

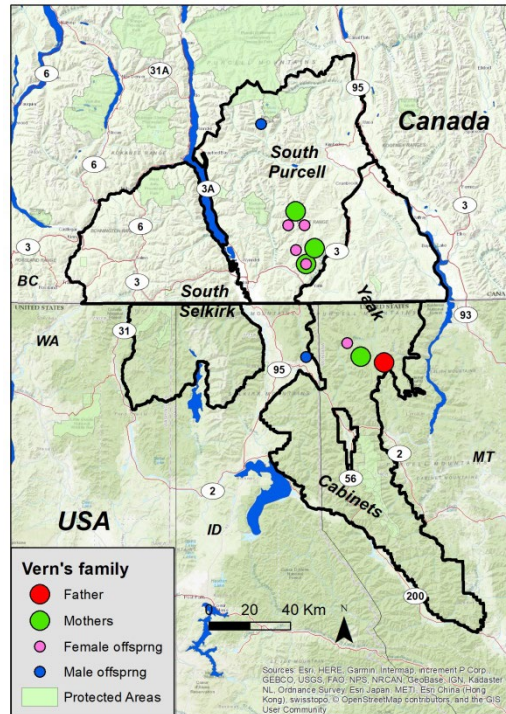


Figure 16: An example of male mediated gene flow across B.C. Highway 3 in the Purcell Mountains. Adult male Vern (red dot) mated with females (green dots) producing various offspring (smaller dots) north and south of B.C. Highway 3. Dot location are individual's capture or hair sample locations.

In summary, the Yahk GPBU is in need of access controls as the road densities in this unit (1.6 km/km^2) are well above the often-used target of 0.6 km/km^2 (Fig. 10a and 18). If this target were adopted and met, there is the potential to double the number of bears in this GPBU (Proctor *et al.* 2021b). The other arena for improved conservation management is along the eastern edge, where human-caused mortalities have accumulated and significantly contribute to lower abundance and fragmentation of this population (Fig. 17, Proctor *et al.* 2018). Conflict reduction measures have been slowly increasing in recent years in this area, so reductions in human-caused mortality are expected. To be fair, implementing access management across the Yahk GPBU will be a challenge due to strong public opposition and heavy industrial timber harvest.

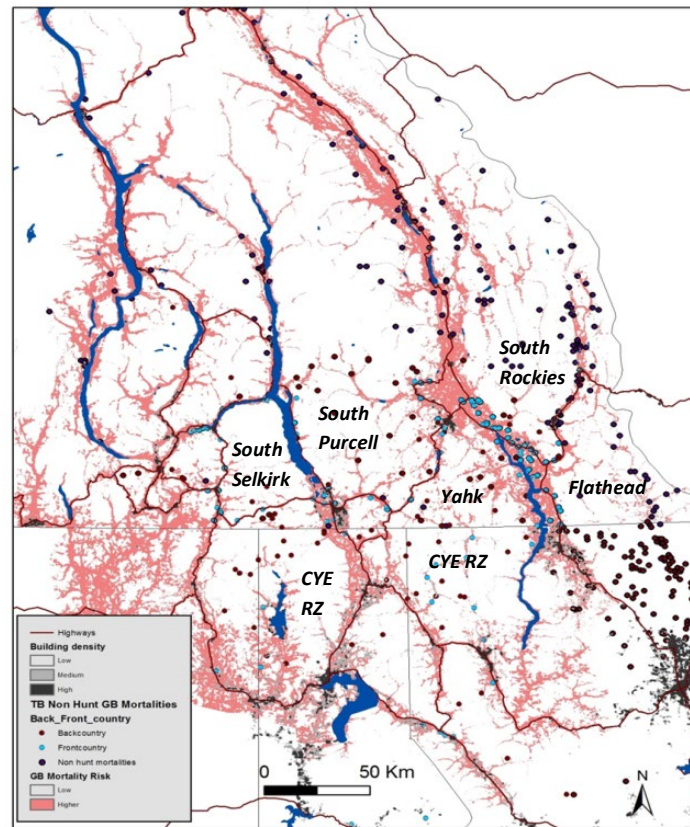


Figure 17: Cumulative non-hunt human-caused grizzly bear mortality in the Canada-U.S. trans-border area between 1984 - 2017. Blue dots are front country mortalities and dark red dots are backcountry mortalities. Red is modeled mortality risk.

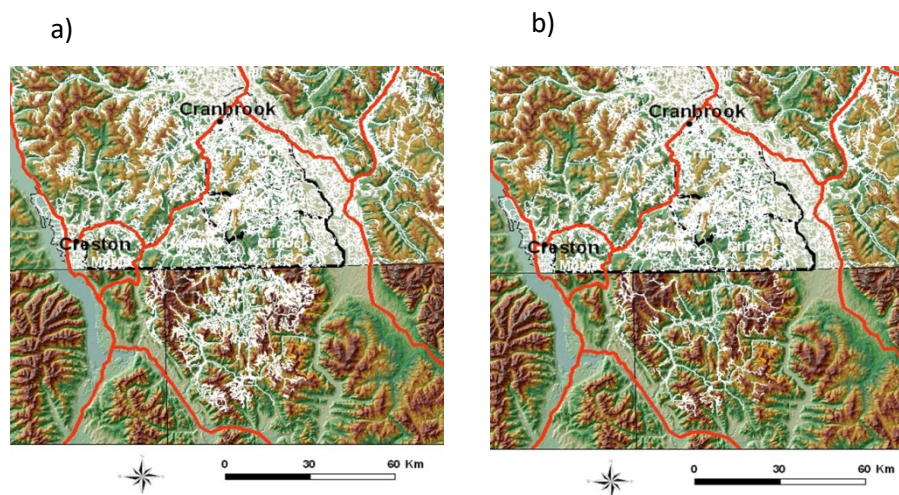


Figure 18: The pattern of access management applied in the international Yahk/Yaak ecosystem **a)** shows the total roads in both the U.S. and Canadian portions, and **b)** the U.S. portion show the open roads after access management has been applied.

South Purcell GBPU

The south Purcell GBPU is directly north of the Yahk unit and still close to the U.S. border (8 km at its closest) and thus plays a role in U.S. grizzly bear recovery (Fig. 15). This unit is designated as M2, high conservation concern, according to the B.C.'s conservation ranking assessment (Fig. 2a, Morgan *et al.* 2020) suggesting that it needs conservation attention. However, it is the southern edge of a larger healthier population of fully connected GBPU's partitioned for management convenience that extends northward approximately 250 km (~150 miles) and contains an estimated 600 grizzly bears (Fig. 3, Proctor *et al.* 2012). The M2 designation reflects threats to this population including, human-caused mortality primarily on the periphery, and extensive forestry roads and the accompanying mortality. As such, this population unit represents the larger population that offers genetic and demographic connectivity to both the South Selkirk and Yahk GBPU's and their associated populations in the U.S. lower 48 states. Efforts to re-establish connectivity across B.C. Highways 3 and 3A would benefit the long-term health of the U.S. South Selkirk and Yaak grizzly bears populations (Figs. 3, 4, and 14) and are ongoing (Proctor *et al.* 2018).

There has been substantial conservation-oriented grizzly bear research in the South Purcell unit by the Trans-border Grizzly Bear Project, in partnership with the USFWS Libby Office. A series of smaller DNA-based population surveys designed to assess fragmentation patterns (but useful for population estimation) were done between 1998 and 2005, and GPS telemetry occurred between 2004-2017. These data were used to estimate abundance, density, habitat quality, important hyperphagia food patches, connectivity corridors, female reproduction, sources and rates of mortality, conflict management, and more (Fig. 15). Proctor *et al.* (2021b) identified and mapped huckleberry patches-important-for-grizzly bears as reported above for other GBPU's (Fig. 15). The average open road density in the unit is 1.0 km/km². The average bear density for the entire unit is 11.9 grizzly bears / 1,000 km² with 73 bears (95% CI, 56-96) estimated from data collected between 2001-2005 (Proctor *et al.* 2021b). This estimate is also 15 years old (in 2021) and the current density of the South Purcell unit is unknown. Grizzly bears in the unit were legally hunted up until the B.C.-wide grizzly bear hunt closure in 2017. Occasionally, the combination of non-hunt conflict mortality and the legal hunt exceeded total mortality limits for this population (Artelle *et al.* 2013). However, the hunt was closed periodically to mitigate the excessive mortalities and allow the bear numbers to recover as per provincial protocol (Hamilton and Austin 2004).

In summary, the South Purcell GBPU could benefit from an organized access management plan to lower road densities particularly around the best huckleberry patches identified in Proctor *et al.* (2021b). Continued and increased efforts to minimise human bear conflicts on the periphery of this unit would also be beneficial for population recovery as well as improving its ability to act as a source population for migrants into the Yahk and the South Selkirks. These two actions would work to increase the potential of connectivity with the Yahk and South Selkirk populations – and ultimately with the U.S. recovery zones of these ecosystems.

Flathead GBPU

The Canadian Flathead GBPU is directly north of the U.S. North Continental Divide Ecosystem (NCDE) recovery zone including portions of the U.S. Glacier National Park (Figs. 4 and 19).

While the two areas are fully connected across the international border, the Canadian Flathead is not a part of the U.S. NCDE recovery zone (Fig. 4). This GBPU is designated as M2, high conservation concern, according to B.C.'s conservation ranking assessment (Fig. 2a, Morgan *et al.* 2020) suggesting that it is in need of conservation attention. This concern comes from threats and fragmentation related to conflict mortality on the unit's periphery along B.C. Highways 3 and 97, forestry roads, and high ungulate hunter density and the accompanying mortality (Proctor *et al.* 2012, Lamb *et al.* 2016, McLellan *et al.* 2018, Morgan *et al.* 2020). Human-caused mortality related to human-bear conflicts on the periphery of this unit remain a significant issue in this unit (Fig. 17, Mowat and Lamb 2016, Lamb *et al.* 2016, Proctor *et al.* 2018). With the goal of future mitigation of these human-caused mortalities, there is an ongoing research project to identify sources of unreported mortality in the area that separates the South Rocky, Flathead and Yahk GPBUs and to inform management actions (C. Lamb, pers. comm.). Recently, attractant management is beginning to be pursued in earnest.

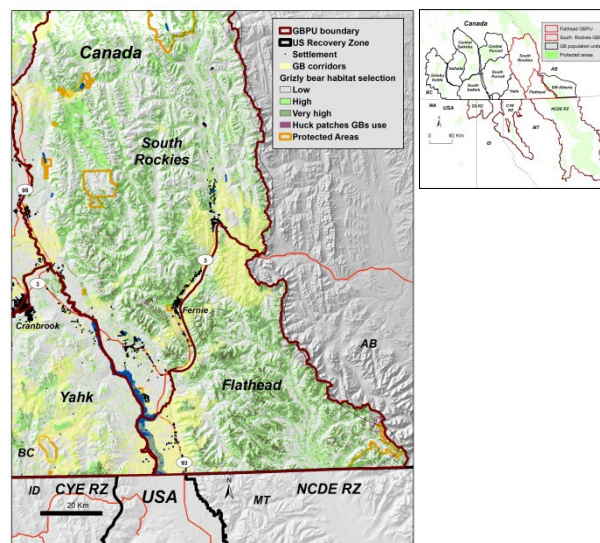


Figure 19: Flathead and South Rockies Grizzly Bear Population Units along the Canada-U.S. border immediately north of the U.S. NCDE Recovery Zone. Habitat selection estimated by resource selection functions (green), grizzly corridors, (yellow), and huckleberry patches (purple) are shown (Proctor *et al.* 2015, 2021).

B.C. Highway 3 transverses the Rocky Mountains east to west and creates the northern boundary of this GBPU as it does in the Purcell Mountains to the west. The big difference is that the number of bears to the south of B.C. Highway 3 in this relatively large biological population includes bears in B.C. (~140), Alberta (~67), and Montana (~1068) totalling > 1200 bears (Fig. 3, Kendall *et al.* 2009, Proctor *et al.* 2012, Mace *et al.* 2012, Morehouse and Boyce 2016, B.C. Min. of FLNRORD 2020, Costello and Roberts 2020, USFWS 2020). While the best (easiest to repair) and most important link to bears in the rest of Canada occurs across B.C. Highway 3, the relatively large size of this international population leaves it fairly secure. While there is evidence of reduced demographic and genetic gene flow across B.C. Highway 3, males have been mediating genetic connectivity (Proctor *et al.* 2005, 2012). However, development along B.C. Highway 3 is ever increasing and the window of opportunity to establish effective wildlife and grizzly bear corridors may be closing. Therefore, if grizzly bear connectivity is a priority in

this area, connectivity management along this transportation and settlement corridor should be pursued.

Canadian bear researcher Dr. Bruce McLellan has been researching bears in the North Fork of the Flathead just north of the U.S. border since the late 1970s. This is one of the most extensively studied bear populations in North America (McLellan and Shackleton 1988, McLellan 1989a, b, c, McLellan and Hovey 1995, 2001a, b, McLellan 2011, 2015, McLellan *et al.* 2018).

McLellan's study area was the southeastern portion of the Flathead GBPU, < 15% of the unit's area. McLellan found a relatively high bear density that undulated with huckleberry productivity roughly corresponding to each of 3 decades between 1979-1988, 1989-1998 and 1999-2010 (McLellan 2015). He concluded that because this population was far from human settlements, and extensive post-forest-fire-induced huckleberry patches were separated from forestry roads in mid-to high elevation open slopes, grizzly bear densities were high relative to other interior non-salmon grizzly bear populations (McLellan 2011, 2015, Mowat *et al.* 2013). He found that densities of bears excluding independent males ranged from 16 -55 bears/1,000 km² in spite of this area receiving the highest per bear capita legal hunt rate (McLellan 2015).

The current density of the entire GBPU is estimated to be 41 bears/1,000 km² (140 bears, B.C. Min of FLNRORD 2020), with an estimated average road density of 0.96 km/km². We note, however, that variability in this road density estimate exists due to access management (B.C. Min. FLNRORD 2017). Of note and in contrast, the density of grizzly bears in the adjacent Yahk GBPU is estimated to be 6.5 grizzly bears/1,000 km², due to a lower huckleberry patch density (30% of the Flathead huckleberry patch density) and higher open road density (1.6 km/km², Proctor *et al.* 2021b). DNA-based surveys have been done across the Flathead GPBU in 1997 and 2007 (Boulanger 2001, Proctor *et al.* 2010). A multi-method (DNA corral & rub trees) monitoring effort has been carried out since 2007 (Mowat *et al.* 2013, Mowat and Lamb 2016). They found that across the entire GPBU, the population declined between 2007 and 2010 and increased again between 2010 and 2014, similar to patterns McLellan (2015) reported for his smaller Flathead study area in the southeast portion of the unit. Grizzly bears in the unit have not been legally hunted since the province-wide hunt closure in 2017.

There has been a significant amount of conservation research and effort related to improving connectivity across B.C. Highway 3 separating the Flathead and South Rocky GBPU's. (Apps *et al.* 1997, Apps *et al.* 2007, Chetkiewicz and Boyce 2009, Clevenger *et al.* 2010, Proctor *et al.* 2012, 2015, Lamb *et al.* 2016, Lee *et al.* 2019). As a result of this attention, a spectrum of groups and government agencies are working to improve wildlife connectivity (including grizzly bears) across B.C. Highway 3 in the Rocky Mountains. Efforts include private land conservation by land trusts within identified linkage corridors, conflict mitigation efforts through WildSafe B.C. and the B.C. COS, and recent updated mitigation planning (Lee *et al.* 2019). A wildlife fencing program is being initiated to funnel wildlife into existing small highway crossing structures and underpasses and a larger wildlife crossing structure is being planned (C. Lamb, pers. comm.). Although, to our knowledge, there are no empirical data evaluating connectivity as a result of these activities, we believe they are likely positive initiatives for grizzly bear connectivity in this region.

South Rockies GBPU

North of B.C. Highway 3 in the Rocky Mountains is the South Rockies GBPU (Fig. 4 and 19). This unit is designated as M2, high conservation concern, according to B.C.'s conservation ranking assessment (Fig. 2a, Morgan *et al.* 2020) suggesting that it is in need of conservation attention. However, it is also the southern edge of a large area of contiguous grizzly bear habitat that extends 150-175 km (~100 miles) north to the Trans-Canada Highway 1 (Fig. 2). As such, this population unit offers genetic and demographic connectivity to bears south of B.C Highway 3. The M2 designation reflects threats to this population including, human-caused mortality primarily on the periphery, and along B.C. Highway 43 that extends north into the unit to Elkford, B.C., extensive forestry roads, high ungulate hunter density and the accompanying mortality.

The South Rocky grizzly bear density is estimated to be 21 bears/1,000 km² (170 bears, B.C FLNRORD 2020). Many of the research and conservation efforts mentioned in the Flathead GBPU section above also apply to this unit as B.C. Highway 3 separates the two units and many efforts work to mitigate the human disturbance from this transportation settlement corridor (mentioned above). Grizzly bears in the unit were legally hunted up until the B.C.-wide grizzly bear hunt closure in 2017. As in the South Purcell GBPU, occasionally the combination of non-hunt conflict mortality and the legal hunt exceeded total mortality limits for this population (Artelle *et al.* 2013, Mowat and Lamb 2016). However, the hunt was closed periodically to mitigate the excessive mortalities and allow the bear numbers to recover as per provincial protocol (Hamilton and Austin 2004). The area continues to have significant human-caused mortality issues (Figs. 12 and 17, Lamb *et al.* 2016, Mowat and Lamb 2016, Proctor *et al.* 2018). Provincial protected areas account for ~500 km² or 6% in the northern portion of the GPBU.

The area has several large coal mines (Fig. 20) and as a result of conservation concerns a Cumulative Effects Management Framework has been instigated and is currently a cooperative effort between the B.C. FLNRORD and the Ktunaxa Nation Council to inform natural resource decisions (<https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/cumulative-effects-framework/regional-assessments/kootenay-boundary/elk-valley-cemf>).

In summary, the conservation situation of the combined Flathead and South Rockies GBPUs is dominated by the fact that south of B.C. Highway 3, the biological population including bears from B.C., Alberta, and the U.S. number > 1200 bears, many of which live in protected areas. In both Canada and the U.S., bears in the Rocky Mountains north and south of B.C Highway 3 represent a potential source of bears for the Yahk/Yaak populations. In that regard, both efforts to minimize conflict-related human-caused mortality on the periphery of these GBPUs is warranted. All indications suggest that there is significant room for improvement in this regard. Also, road management is warranted in some areas to allow survival of inter-population migrants.



Figure 20: Coal mines in the Flathead Elk Valleys in southeast British Columbia.

British Columbia Summary

Connectivity

While perfect evidence is often lacking, it appears that connectivity across B.C. Highway 3 and 3A across southern B.C. is increasing, at least in some locations (Tables 1, 2). This is not likely the case in the North Cascades or the Granby Kettle GBUs, but that possibility exists in the Granby-Kettle if population numbers continue to expand within that GBU as they have over past 2 decades (Lamb *et al.* 2018). Highway 3 in the Granby-Kettle has virtually no human-settlement and likely would allow grizzly bear permeability. However, for this to occur it might require a unit-wide motorized access management plan be implemented that allowed for increased numbers of bears (OAG 2017, Proctor *et al.* 2021b).

Connectivity to U.S. grizzly bear populations has the most to gain from the Canadian portions of the South Selkirk and Yaak Recovery zones. For this to be realized, connectivity must be further improved across B.C. Highways 3 and 3A, to the larger Purcell grizzly bear population to the north. Connectivity into the South Selkirks across B.C. Highway 3A and across B.C. Highway 3 into the Canadian Yahk (fully connected to the CYE RZ) from the South Purcell Mountains is increasing (Proctor *et al.* 2018), and challenges predicting the future aside, is likely to continue improving. The same can be said for connectivity across B.C. Highway 3 in the Rocky Mountains north of the NCDE. Higher densities of bears in that area provide more possibilities for enhanced connectivity, but continued efforts to reduce human-caused mortality should be a priority. In other words, while the connectivity situation in Canada is improving, more work is required.

Table 1: Summary of trends in connectivity and abundance of Grizzly Bear Population Units in Southern B.C just north of the U.S. border.

GBPU	Trend	
	Connectivity	Abundance
North Cascades	No	No
Granby Kettle ¹	Unknown	Increasing
South Selkirk ²	Increasing	Increasing
Yahk ²	Increasing	Unknown
Flathead ³	Unk, possibly increasing	Stable

¹ Lamb *et al.* (2018)² Proctor *et al.* (2018)³ McLellan (2015)**Table 2:** Summary of conservation management being applied within Grizzly Bear Population Units in southern B.C. just north of the U.S. border (access mgt refers to motorized management)

GBPU	Conservation management to improve:		Specific mgt actions		
	Connectivity	Population size	Non-lethal conflict response	Access mgt	Attractant mgt
North Cascades	No	No	No	No	No
Granby Kettle	No	Some access mgt	Some	Some	Yes
South Selkirk	Yes	Considerable	Yes	Some	Yes
Yahk	Yes	Some	Yes	No	Yes
Flathead	Some	Some access mgt	Some	Some	Yes

Abundance

Minimizing human-caused mortality and maintaining stable grizzly bear populations in Canada is also beneficial for the shared international populations. We summarize grizzly bear abundance trends in Table 1. There has been no recovery of grizzly bears in the North Cascades in the past 20 years. The Granby-Kettle has experienced a significant increase in bears in the past 20 years and further increases may require a unit-wide motorized access management plan (Lamb *et al.* 2018). Preliminary indications are that bears in the Canadian South Selkirk population are increasing (Kasworm *et al.* 2020a) and human-caused mortality is on a downward trend (Proctor *et al.* 2018). Further increases may also require more widespread access management beyond NCC lands within this unit (MacHutchon and Proctor 2016, Proctor *et al.* 2020, 2021b). An ongoing DNA survey (began in 2020) will verify this within 2021. The population trend in the Canadian Yahk is less clear, except that the international Yahk/Yaak has recently shown to be

increasing – how much of that is due to Canadian bears is uncertain. Road densities remain relatively high in the Canadian Yahk and this is where conservation effort needs to focus in this population (Proctor *et al.* 2020, 2021). The Flathead has a relative high density of bears, relative to neighbouring GBPU, and has undulated over the decades around what might be considered a stable mean over time (McLellan 2015).

Motorized Access Management

Managing backcountry motorized vehicle access remains a challenge in B.C. While several localised motorized access management plans are being implemented (mentioned above), none of them have set targets to meet. Further, despite compelling evidence detailing the benefits of motorized access management to grizzly bear conservation and continued recommendations by scientists to implement a robust motorized access management plan (e.g., Boulanger and Stenhouse 2014, Lamb *et al.* 2018, Proctor *et al.* 2020, Proctor *et al.* 2021b), there is currently no region-wide plan – nor are there plans to develop one (Garth Mowat, B.C. Provincial Large Carnivore Specialist, FLRNORD, pers. comm.). Overcoming public resistance to motorized vehicle closures on a regional scale is challenging, particularly in the absence of pertinent legislation (OAG 2017).

To further work on motorized access management, the Trans-border Grizzly Bear Project is currently working on an analysis wherein they will use their recent huckleberry ‘patches-important-for-grizzly-bears’ model (Proctor *et al.* 2021b) as the basis for the development of a proposed motorized access management plan that optimizes the benefit to grizzly bear while simultaneously minimizing inconvenience to people. This work is informed by the literature review in Proctor *et al.* (2020) and recent results of Proctor *et al.* (2021b) that demonstrate that huckleberry patches in areas of high road density do not contribute significantly to bear densities. They will use the results of this new project as the basis for conversations with government officials with the goal of furthering the completion of motorized access controls in the South Selkirk, Yahk, and South Purcell GBPU.

One final note, it is clear from the situation in British Columbia that the U.S. recovery ecosystems would benefit significantly from continued cooperation and collaboration with researchers, ENGOs, First Nations, and governments in Canada, but Canadian populations are not a panacea for recovery of populations in the U.S. along the Canadian border. The Yahk and South Selkirk populations are small physically as a result of mountain valleys and human transportation and settlement patterns. These physical limitations necessitate that these small populations become and remain connected to adjacent and larger populations over the long-term. That connectivity will not likely be a free flow of bears, but rather a limited number of individuals that move and survive through the human-dominated landscapes that make up the fractures. Thus, while it is essential that the smaller U.S. populations remain connected to Canadian populations, that connectivity is a hedge against losses of genetic diversity, an opportunity for natural demographic rescue and augmentation, and, in the extreme, a resistance against extirpation. The ultimate health of the bears in U.S. ecosystems, and those in Canada also requires that they be healthy populations internally, attained through minimized human-caused mortality and good habitat management.

Alberta Overview

Alberta is the eastern edge of grizzly bear distribution in western Canada (excluding territories north of the 60th parallel) (COSEWIC 2012). Primary grizzly bear habitat includes the Rocky Mountain and Foothills Natural Regions as well as the Central Mixwood Subregion of the Boreal Forest Natural Region (COSEWIC 2012). Alberta grizzly bears were first designated as a fur-bearer in 1928, but that changed the subsequent year (1929) when they became a big game animal (Festa-Bianchet 2010). More stringent hunting regulations were established in the 1960s and by 1988 a draw system and hunting quotas were in place (Festa-Bianchet 2010). In 2002, Alberta's Endangered Species Conservation Committee recommended that grizzly bears be designated as *Threatened* on the basis of the species' small population size, slow reproductive rate, increasing human activity in grizzly bear habitats, and limited immigration from populations outside of Alberta (Alberta Sustainable Resource Development 2008). That recommendation, however, was not accepted by the Minister of Sustainable Resource Development (Festa-Bianchet 2010). A recovery team was appointed, a recovery plan was developed, and from 2004 through 2008, a series of DNA-based population inventories occurred across the province (Alberta Sustainable Resource Development 2008, Festa-Bianchet 2010). Also during this time period, a moratorium on grizzly bear hunting was established in 2006 (Festa-Bianchet 2010); the moratorium continues to be in place at the time of this document, although First Nation subsistence hunting is still allowed. Grizzly bears were listed as *Threatened* under Alberta's Wildlife Act in June 2010 (Alberta Environment and Parks 2016). The 2010 grizzly bear status assessment estimates the current total population of grizzly bears in Alberta as 691 plus additional bears in portions Banff and Jasper National Parks (Festa-Bianchet 2010). This estimate is based on the 2004-2008 DNA inventory data, habitat modelling, and expert opinion.

In 2016, Alberta Environment and Parks drafted an updated grizzly bear recovery plan (Alberta Environment and Parks 2016). Although the updated plan has not yet been approved by the Minister, it guides current grizzly bear management in the province. Alberta is divided into six different bear management areas (BMA, Alberta Environment and Parks 2016). Each BMA is further divided into a Recovery Zone and a Support Zone (Fig. 21a, Alberta Environment and Parks 2016). The Recovery Zone is the area in which the province intends to recover grizzly bears, while the Support Zone is intended to allow for grizzly bears whose home ranges are not entirely within the Recovery Zone; management of bear attractants and other sources of human-wildlife conflict in the Support Zone are completed with the intent of supporting the grizzly bear population in the Recovery Zone (Alberta Environment and Parks 2016). Within the Recovery Zone, there are Core and Secondary Zones which inform Recovery Zone management (Fig. 21b, Alberta Environment and Parks 2016). The new plan also identifies Habitat Linkage Zones which identify highway corridors where there is a risk of populations becoming more isolated over time (Alberta Environment and Parks 2016). Updated DNA-based population inventories were completed cross the province from 2011-2018; some density and abundance estimates have been released and others are still forthcoming. Updated population estimates for some BMAs suggest a population increase (Stenhouse *et al.* 2015, Morehouse and Boyce 2016). Because an updated provincial estimate has not yet been completed, the population estimate of 691 (plus additional bears in the mountain National Parks) currently guides grizzly bear management (Alberta Environment and Parks 2016). Threats to grizzly bears across the province include

anthropogenic habitat alteration, loss of connectivity, and human-caused grizzly bear mortality (Alberta Environment and Parks 2016).

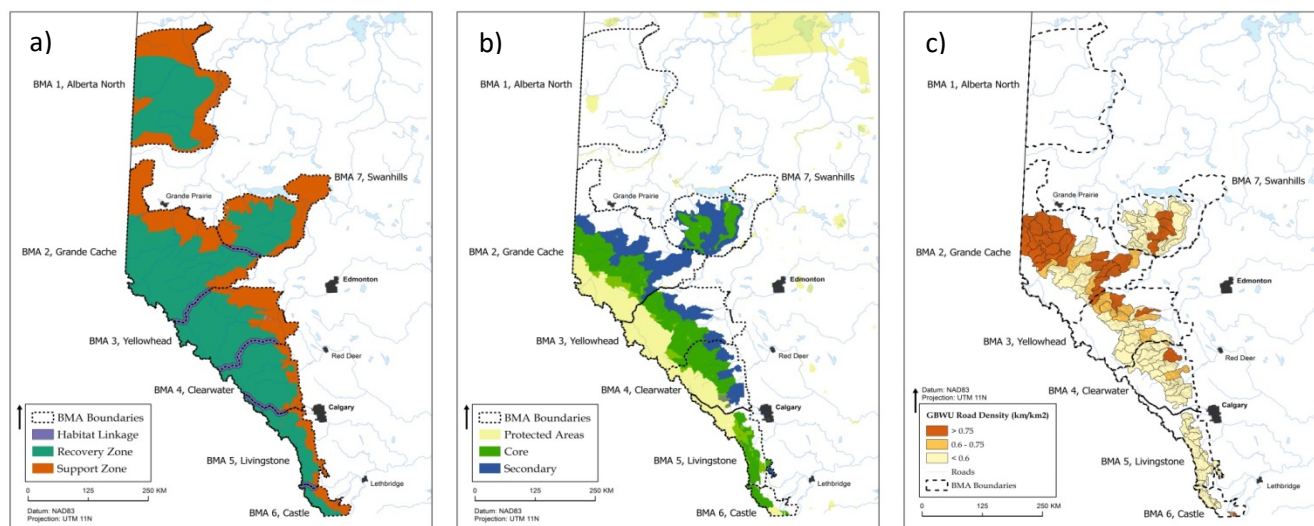


Figure 21: Grizzly Bear Management Areas (BMAs), (b) Core and Secondary habitats (adapted from Nielsen *et al.* 2009), and (c) Road density categories by Grizzly Bear Watershed Units across 7 BMAs in western Alberta (AEP 2016, adapted from Proctor *et al.* 2020).

Like many areas of North America, the anthropogenic habitat alteration caused by roads is a primary concern for grizzly bears in Alberta. Roads allow humans motorized access into high-quality grizzly bear habitat (Nielsen *et al.* 2004, Schwartz *et al.* 2006), and human-related causes are the primary source of grizzly bear mortality across North America, even in unhunted landscapes (Peek *et al.* 1987, McLellan *et al.* 1999, Benn and Herrero 2002, Garshelis *et al.* 2005, Schwartz *et al.* 2006, McLellan 2015, Proctor *et al.* 2020). Increased road densities are linked to changes in bear movements, distributions, and behaviour; increased mortality risk; and decreased survival and reproduction (Roever *et al.* 2008, Northrup *et al.* 2012a, Boulanger *et al.* 2013, Boulanger and Stenhouse 2014). While road density itself is related to grizzly bear survival, traffic volume is also likely to influence bear behaviour and mortality risk (Northrup *et al.* 2012a, Boulanger and Stenhouse 2014). For example, in southwestern Alberta, grizzly bears use private agricultural lands that have a high road density but lower human use relative to the multi-use public lands (Northrup *et al.* 2012a). In Alberta, demographic models have suggested a road density threshold of 0.75 km/km² below which the survival of female grizzly bears with cubs is reduced (Boulanger and Stenhouse 2014). The current recommended road density thresholds within Alberta's draft recovery plan are 0.6 km/km² in the Core Zone and 0.75 km/km² in the Secondary Zone (Fig. 21c, Alberta Environment and Parks 2016), but there are regional differences in the enactment of these recommendations and there is no province-wide mandate requiring their implementation. Additionally, there is a lack of clarity in terms of what constitutes a closed or restricted road that should be excluded from open-road density calculations (Proctor *et al.* 2020). Further, most BMAs have at least some grizzly bear watershed units that exceed these recommendations (Fig. 21c, Alberta Environment and Parks 2016, Proctor *et al.* 2020). Habitat alteration in the form of linear features can also impact grizzly bears. Linear features developed for oil and gas exploration often become recreational trails over

time, used by off highway vehicles (OHVs). Ladle's (2017) work suggests that some bears respond negatively to high levels of OHV use on trails. Although closing or restricting motorized access in high quality bear habitat has been identified as a powerful tool in grizzly bear management (Mace *et al.* 1996, Roever *et al.* 2010, Schwartz *et al.* 2010, Northrup *et al.* 2012a, Boulanger and Stenhouse 2014, Proctor *et al.* 2020), there is not currently a provincial motorized access management plan. Access management planning is part of Regional Land Use Plans and it is through that framework that any future motorized access management will be implemented (Alberta Environment and Parks 2016). Although portions of Alberta's BMAs are subject to varying motorized access management plans as part of a protected area designation or a Public Land Use Zone, these plans do not necessarily include the recommended grizzly bear road density thresholds (Alberta Environment and Parks 2016). Indeed, one of the recommended recovery actions within the current draft recovery plan is that grizzly bear road density thresholds be incorporated into regional access management planning (Alberta Environment and Parks 2016).

Loss of connectivity between grizzly bear populations is also a concern at the provincial level. Proctor *et al.* (2012) demonstrated that major east-west highways in Alberta have resulted in differentiation in the genetic structure of bear populations; this genetic separation is greater than the effect of the continental divide separating Alberta and British Columbia. Highway 1 which bisects Banff National Park and Highway 3 through the Crowsnest Pass are particularly problematic (Proctor *et al.* 2012). To address the connectivity concern for wildlife, Banff National Park has installed 6 overpasses and 38 underpasses since 1996 (Ford *et al.* 2010). Research has shown both male and female grizzly bears use these highway crossing structures and there is evidence of bidirectional gene flow across the highway (Sawaya *et al.* 2014). In southwestern Alberta, Highway 3 bisects several small communities that collectively make up the Crowsnest Pass. Several groups are currently working collaboratively to try and develop crossings structures for Highway 3 (<https://y2y.net/work/hot-projects/highway-3-wildlife-friendly/>). To date, Alberta Transportation has installed jump-outs and wildlife fencing in the Crowsnest Pass. An underpass and wildlife fencing along Hwy 3 near Rock Creek in southwestern Alberta is included in the 2020 provincial highway budget and both projects are currently in the design stage (Alberta Government 2020). Additionally, there are several attractant management initiatives in the Crowsnest Pass lead primarily by the Crowsnest Pass BearSmart (discussed in more detail below).

Human-caused grizzly bear mortality also threatens grizzly bear populations in Alberta. Provincially, the greatest sources of human-caused mortality in order of prevalence are poaching, accidental collisions with highway vehicles or trains, self-defence kills, and misidentification of a grizzly bear as a black bear by hunters (Alberta Environment and Parks 2016). Grizzly bear mortality due to trains is particularly problematic in the mountain parks (St. Clair *et al.* 2020). Current provincial recovery objectives are to ensure that the known human-caused mortality rate for grizzly bears is $\leq 4\%$ of which the female mortality rate is $\leq 1.2\%$ for all BMAs except for the southwestern corner of Alberta (BMA 5 and 6) where the known mortality rate is $\leq 6\%$ and $\leq 1.8\%$ for female grizzly bears (Alberta Environment and Parks 2016).

Human-grizzly bear conflicts remain a challenge and can result in grizzly bears being translocated or killed. Within Alberta, when an individual has a complaint regarding grizzly

bears, they have the option of reporting it to the Fish and Wildlife division of the provincial government. The details of the event are recorded as a text summary in a provincial occurrence database. Complaints are investigated by trained government staff. The government response to grizzly bear occurrences is guided by the provincial grizzly bear response guide (Alberta Government 2016). In most situations, if the bear is not an immediate threat to humans, preventative action is the first response (Alberta Government 2016). Preventative responses can include any of the following: area closure/motorized access restrictions, monitoring, providing educational materials, attractant removal, electric fencing, hazing or aversive conditioning, or hard release of capture bears (Alberta Government 2016). Four main criteria are used to determine the government's response to human-bear conflict, including: age, sex, and reproductive status of the bear, location of the incident (e.g., Recovery Zone vs. Support Zone), the bear's behaviour, and the bear's known conflict history (Alberta Government 2016). Captured bears can be relocated within the same BMA, relocated outside of the BMA, or euthanized. In the case of orphaned cubs, retention in captivity is also an option (Alberta Government 2016). Provincially, captured bears were translocated out of the BMA 87% of the time (Alberta Environment and Parks 2016).

South of Highway 3 – BMA 6

BMA 6 is bounded by Highway 3 to the north, British Columbia to the west, Montana to the south, and the approximate edge of grizzly bear habitat to the east (Fig. 22). Protected lands in this area include Waterton Lakes National Park, Castle Provincial Park, Castle Wildland Provincial Park, and Beauvais Lakes Provincial Park. The remainder of the public lands are crown land under the jurisdiction of the Alberta government. The Recovery Zone in BMA 6 is 1,814 km², while the Support Zone is 1,774 km². The Support Zone consists almost exclusively of privately owned lands, which are used predominately for agriculture – both livestock and crop production (Statistics Canada 2006). On the north end of BMA 6 is a Habitat Linkage Zone encompassing the Highway 3 region that divides BMA 5 and BMA 6. Southwestern Alberta is known for its strong winds, and there is a sharp transition from mountainous terrain in the west to prairies and agricultural lands in the east; there are limited foothills.

The grizzly bear population in Alberta's BMA 6 is contiguous with Montana's NCDE grizzly bear population as well as British Columbia's Flathead grizzly bear population. The most current density estimates for males in this BMA are 8.0/1,000 km² in the Recovery Zone and 7.1 male/1,000 km² in the Support Zone (Morehouse and Boyce 2016). For females, density estimates are 12.4/1,000 km² in the Recovery Zone and 10.0/1,000 km² in the Support Zone (Morehouse and Boyce 2016). The expected abundance of resident grizzly bears in BMA 6 is 67.4 (Morehouse and Boyce 2016). These numbers represent a 4% per year increase from the previous BMA 6 abundance estimate of 51 grizzly bears (Alberta Grizzly Bear Inventory Team 2008, Morehouse and Boyce 2016). It should be noted, however, that the methods were not identical between the 2007 and 2014 abundance estimates (Alberta Grizzly Bear Inventory Team 2008, Morehouse and Boyce 2016). BMA 6 is a small portion of a much larger ecological population and Morehouse and Boyce (2016) estimated that approximately 172 grizzly bears use the area each year. The area was also sampled in 1997 in conjunction with an additional DNA grid north of Highway 3 (Mowat and Strobeck 2000). The Mowat and Strobeck (2000) abundance was 74 bears (95% CI 60-100), but the grid sampled a larger area, and the estimates are not directly comparable.

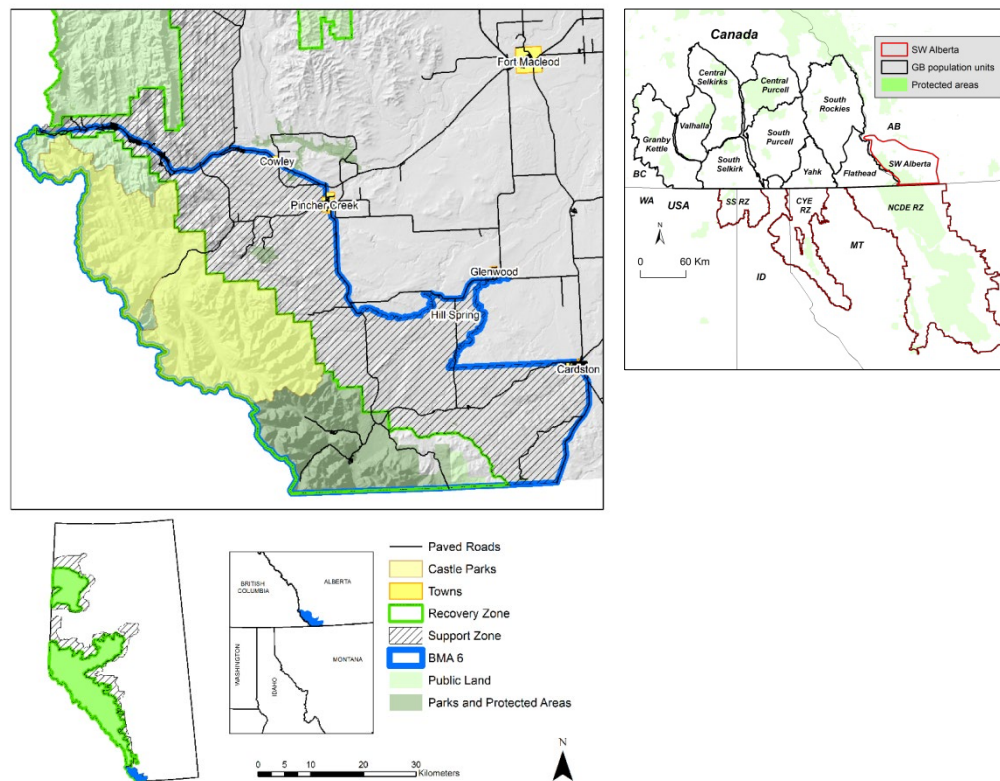


Figure 22: Grizzly bear management unit north of the Canada-U.S. border in southwest Alberta relative to the NCDE Recovery zone.

The Recovery Zone of BMA 6 is a multi-use landscape where uses include oil and gas development, forestry operations, cattle grazing, and several recreational activities (e.g., hiking, mountain biking, camping, OHV use, skiing, etc.). Much of the Recovery Zone has recently (2017) been designated as the Castle Parks (Fig. 22, Castle Wildland Provincial Park and Castle Provincial Park), which is likely positive for bears as much of the area within the Recovery Zone has been identified as high-quality habitat for grizzly bears (Nielsen *et al.* 2009, Northrup *et al.* 2012b, Farr *et al.* 2017). Indeed, the Recovery Zone of BMA 6 contains areas of high habitat productivity, including several species of fruiting bear foods (Braid and Nielsen 2015). Although the road density at the watershed scale in the Castle region is relatively low (average 0.2 km/km²) and below the suggested grizzly bear threshold of 0.6 km/km² (Farr *et al.* 2017), the total average linear footprint density (including off road vehicle trails) of 2.0 km/km² is over two times higher than that found in other parks of Alberta (Farr *et al.* 2017). The Castle Management Plan states that it will, “*Monitor recreational trail use and, if necessary, limit density and frequency of use to minimize stressors on grizzly bears*” (Alberta Environment and Parks 2018). Specific road density thresholds, however, are not included within the plan. Within the entirety of BMA 6, 37.5% (3 out of 8) grizzly bear watershed units in the Core Zone have road densities that exceed the recommended road density of 0.6 km/km². Further, this area has high traffic volumes, and traffic patterns have caused a distinct behaviour shift in grizzly bears with bear use

of areas near roads and crossing of roads occurring at night when traffic is low (Northrup *et al.* 2012a, b). As an example of the juxtaposition of good habitat and mortality risk, Braid and Nielsen (2015) identified both source-like habitats (i.e., areas with high habitat productivity and low mortality risk) and sink-like habitats (i.e., areas with high habitat productivity and high mortality risk). They then used simulated annealing to prioritize these sites and identify areas where future development should be limited and road-related mortality risk should be mitigated (Braid and Nielsen 2015). Many of these high priority sites are within the Recovery Zone (Braid and Nielsen 2015). Thus, while the Recovery Region contains important bear habitat, it is not without challenges.

Outside of the Recovery Zone, the Habitat Linkage zone identifies the area of southwestern Alberta where there is a need to maintain or enhance the ability of grizzly bears to move between adjacent BMAs. As noted in the Alberta overview, Highway 3, which bisects the towns of the Crowsnest Pass, represents a barrier to movement for grizzly bears in this region (Proctor *et al.* 2012). Indeed, genetic work has revealed a limited number of bears cross the highway. Population inventory work occurred in the adjacent BMA 5 (north of Highway 3) in 2014 (northern half of BMA 5) and 2016 (southern half of BMA 5). Out of the >300 genotypes that were detected in the BMA 5 and BMA 6 inventory work, there were 9 bears (6 M, 3 F) that were detected both north and south of Highway 3 (Morehouse 2018). Of these 9 bears, 2 of them were translocated into BMA 5 from BMA 6 because of conflicts (Morehouse 2018). It is possible that additional bears were translocated between the BMAs and no hair samples were collected; some of the redetections are unlikely as natural movements (Morehouse 2018).

To help address the connectivity issue for grizzly bear, Chetkiewic and Boyce (2009) developed resource selection functions for grizzly bears in the Crowsnest and found that grizzly bear habitat selection was positively associated with greenness in all seasons and soil wetness and proximity to water in the summer – and both of these variables were associated with grizzly bear forage. Using these RSFs and least cost path analysis Chetkiewic and Boyce (2009) suggested potential highway crossing zones for the Crowsnest Pass. Highway 3 is a barrier for not only grizzly bears, but numerous wildlife species (Apps *et al.* 2007), and several organizations are working together to try and implement crossing structures (Clevenger *et al.* 2010).

In BMA 6, the Support Zone is almost exclusively private lands and there is extensive overlap between grizzly bear home ranges and human land uses (Fig. 23, Northrup *et al.* 2012b, Farr *et al.* 2017). The private lands of BMA 6 contain favourable grizzly bear habitat and often have lower human use than the adjacent public lands (Northrup *et al.* 2012, Northrup *et al.* 2012b). However, several attractants exist and the propensity for conflict is higher on private lands (Northrup *et al.* 2012b). Indeed, much of the private land within BMA 6 has been identified as an ecological trap for grizzly bears (Northrup *et al.* 2012). While grizzly bear-human conflicts are a concern across the province, southwestern Alberta is a hotspot (Alberta Environment and Parks 2016, Morehouse and Boyce 2017a). Most grizzly bear incidents in the area are related to some sort of attractant and the primary attractants for grizzly bears are grain and dead livestock (Morehouse and Boyce 2017a). Depredation of livestock is also a concern and depredation events have been increasing in recent years (Morehouse *et al.* 2018, Morehouse *et al.* 2020). Grizzly bear occurrences have also been spreading eastward over the last decade and grizzly

bears now occur on prairie habitats outside of the provincially designated BMA boundaries (Fig. 23, Morehouse and Boyce 2017a). Research also suggests that conflict behaviours might be being passed down from females to their offspring, potentially exacerbating the human-bear conflict problem (Morehouse *et al.* 2016). As a result of conflicts, grizzly bears can be translocated according to the grizzly bear response guidelines (Alberta Government 2016). Between 2009 and 2013, 42 grizzly bears were captured and translocated outside of BMA 6 – the highest number for the province for that time period (Alberta Environment and Parks 2016).

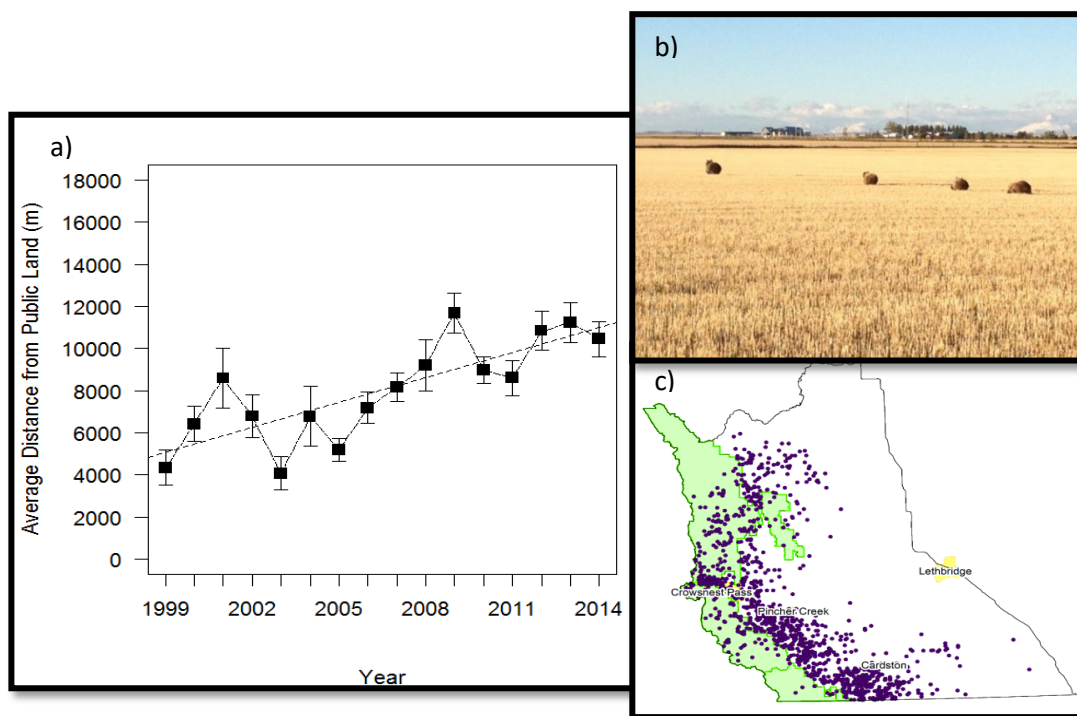


Figure 23: Increasing use of agricultural lands by grizzly bears to the east of the Rocky Mountains and foothills in southwest Alberta. Occurrence records (i.e., complaint data) show an eastward expansion over time (a, c). Photo (b) provided by Lyle Lester, Alberta Solicitor General. Adapted from Morehouse and Boyce (2017).

There are several initiatives in BMA 6 to try and mitigate or reduce human-grizzly bear conflicts including the Crowsnest Pass BearSmart program, the provincial intercept-feeding program, and the Waterton Biosphere Reserve's Carnivores and Communities Program. The Crowsnest Pass BearSmart Program is part of Alberta's provincial BearSmart effort, which aims to provide Albertans with the necessary information to make safe decisions while in bear country, keep bears safe, prevent bear encounters, and reduce bear-caused property damage (<https://www.alberta.ca/alberta-bearsmart-program-overview.aspx>). Garbage is one of the primary attractants in the Crowsnest Pass (Morehouse and Boyce 2017a). Although most human-bear conflicts in the Crowsnest Pass are related to black bears, grizzly bears are present as well (Morehouse and Boyce 2017a). The program works on several attractant management initiatives including attractant removal for seniors and other individuals unable to remove attractants such as apples or fruit trees, bear-resistant garbage cans for loan, and partnerships with municipal

governments to develop bylaws aimed at assisting and enforcing the reduction of attractants (www.cnpbearsmart.com).

Specific to BMA 6, was the intercept feeding program wherein the provincial government slung road-killed ungulate carcasses into remote high elevation areas where grizzly bears were likely to encounter them once they emerged from hibernation. The program began in 1998 with the goal of reducing grizzly bear depredation of livestock during the spring calving season. Typically, two carcass drops occurred each year, once in mid-March and once in mid-April. Morehouse and Boyce (2017b) evaluated the program using non-invasive genetic sampling, remotely-triggered trail cameras, and provincial complaint records. They found that the program was used largely by male grizzly bears and that grizzly bear depredation of livestock did not decrease during the intercept-feeding program nor did it increase after the program was suspended (Morehouse and Boyce 2017b). Annual operating costs for the program were estimated to be \$43,850 CAD with an initial \$19,000 CAD investment (Morehouse and Boyce 2017b). Thus, their results suggested that other mitigation efforts such as electric fencing of calving pastures might be a more cost-effective long-term solution (Morehouse and Boyce 2017b).

Perhaps the most active human-bear conflict mitigation initiative in BMA 6 is the Waterton Biosphere Reserve's (WBR) Carnivores and Communities Program (CACP). The program works with landowners, farmers, ranchers and rural residents to advance its goal of supporting coexistence between people and large carnivores. The program began in 2009 and the Alberta government is one of its primary funders and partners. The CACP has three primary on-the-ground initiatives: deadstock removal, cost-shared attractant management projects, and bear safety workshops. The deadstock removal program provides a direct service to livestock producers whereby livestock carcasses are picked up and completely removed from the property. Cost-shared attractant management projects are things such as electric fencing, bear-resistant grain bin doors, and upgraded grain storage that restrict bear access to agricultural attractants. Grain and deadstock are the primary bear attractants in this area (Morehouse and Boyce 2017a).

Finally, bear safety workshops have been developed in partnership with the Alberta government to specifically target farm and ranch families. The efficacy of the CACP was recently evaluated using a social survey and review of complaint records; both attractant and deadstock-based grizzly bear incidents changed from increasing to decreasing after the implementation of the CACP program in 2009; livestock depredation by grizzly bears, however, remains a challenge (Fig. 24, Morehouse *et al.* 2020).

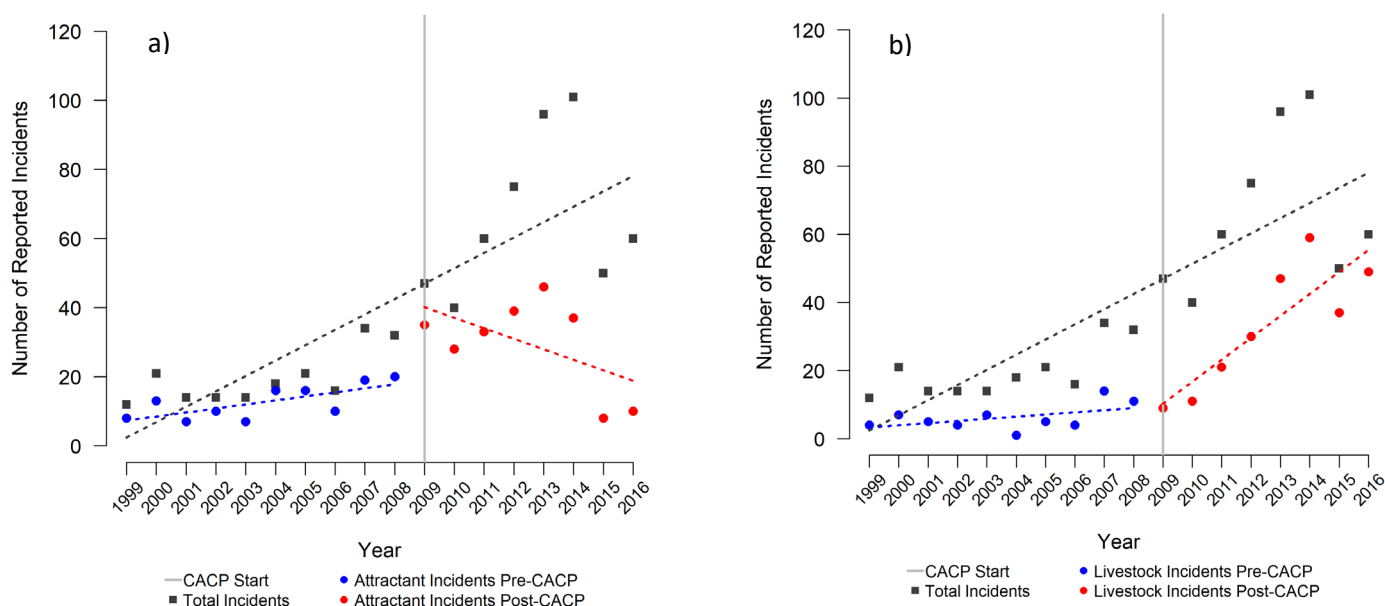


Figure 24: Reported grizzly bear attractant (a) and livestock (b) incidents before and after the implementation of conflict reduction management by the Waterton Biosphere Reserve's Carnivores and Communities Program (CACP) in southern Alberta which started in 2009. Adapted from Morehouse *et al.* (2020).

Yukon, Northwest Territories, and Nunavut

There are approximately 11,500-14,000 grizzly bears within Canada north of the 60th parallel in North America (Fig. 1. Yukon, 6,000-7,000, Northwest Territories 4,000-5,000, Nunavut 1500-2000, COSEWIC 2012). Grizzly bear populations in this region are generally sustainable and appear to be expanding north into the islands of the Arctic Ocean (Fig. 1, McLellan *et al.* 2017b). Bears are legally hunted in several local jurisdictions where habitat productivity is sufficient for a sustainable hunt (Yukon Conservation and Management Plan Working Group 2019). While human population densities are very low relative to southern Canada, grizzly bears are still susceptible to human disturbance and conflict mortality. As such, each territory has conflict reduction and human safety guidelines for living and working with bears (Yukon Conservation and Management Plan Working Group 2019, NWT, <https://www.enr.gov.nt.ca/en/services/bear-safety>). The distance between the bears in the lower-48 States and these northern populations is such that there is no link between them in terms of connectivity, genetic or demographic (Proctor *et al.* 2012).

Alaska

Grizzly bears, or brown bears as they are often called in Alaska, occupy most of Alaska except several islands along the southeast coast, the furthest portions of the Aleutian Island chain, and the lower reaches of the Yukon River in extreme southwest Alaska (Fig. 1). Grizzly bear densities in Alaska range widely from > 175 bears/1,000 km² in coastal populations where

salmon are the primary food, to < 40 bears/1,000km² in interior populations, to < 7 bears/1,000km² in northern coastal plains areas (Miller & Schoen 1999). This variation in bear density is thought to be related to a region's bear food productivity (Hilderbrand *et al.* 1999, 2019, Mowat *et al.* 2013). Alaska has the largest grizzly bear population of any jurisdiction in North America (Fig. 1, Miller and Schoen 1999). While a state-wide rigorous estimate of abundance is not available, manager and expert-derived estimates suggest there may be between 25,000 – 39,000 bears and, state-wide, the population is considered to be stable in abundance and distribution (Miller and Schoen 1999). That said, there are localized issues with conflict and hunt controversies (Peirce and Van Daele 2006, Miller *et al.* 2017).

Alaska is home to the only other sub-species of brown bear in North America – the bears of Kodiak Island (*Ursus arctos middendorffi*), of which there are an estimated 3,500 (Rausch 1963, Talbot and Shields 1996, Paetkau *et al.* 1998 a and b, Alaska Department of Fish and Game <https://www.adfg.alaska.gov/index.cfm?adfg=brownbear.trivia>). Kodiak's brown bears have been isolated from the mainland for approximately 12,000 years and have a relative low genetic diversity but show no negative population attributes due to inbreeding depression (Paetkau *et al.* 1998a and b).

Literature Cited

- Alberta Environment and Parks. 2016. Alberta Grizzly Bear (*Ursus arctos*) Draft Recovery Plan. Alberta Environment and Parks, Alberta Species at Risk Recovery Plan No. 38. Edmonton, AB.
- Alberta Environment and Parks. 2018. Castle Management Plan: Castle Provincial Park and Castle Wildland Provincial Park. Available at: https://www.albertaparks.ca/media/6494620/castle_management_plan.pdf. Accessed 29 January 2021.
- Alberta Government. 2016. Grizzly bear response guide. Alberta Environment and Parks, Fish and Wildlife, no. 1. ISBN 978-1-4601-2714-8. Available at: <https://open.alberta.ca/dataset/34f0b200-0df7-4b3c-8752-cdca6fcbe560/resource/28450e52-4d54-4804-8493-5050c71c5ac9/download/grizzlybearresponseguide-2016.pdf>. Accessed 15 December 2020.
- Alberta Government. 2020. 2020 provincial construction program highway and water management projects. Available at: <https://www.alberta.ca/assets/documents/trans-2020-provincial-construction-program.pdf>. Accessed 27 January 2021.
- Alberta Grizzly Bear Inventory Team. 2008. Grizzly bear population and density estimates for Alberta bear management unit 6 and British Columbia management units 4-1, 4-2, and 4-23 (2007). Report prepared for the Alberta Sustainable Resource Development, Fish and Wildlife Division, British Columbia Ministry of Forests and Range, British Columbia Ministry of Environment, and Parks Canada. Integrated Ecological Research, Nelson, Canada.
- Alberta Sustainable Resource Development. 2008. Alberta Grizzly Bear Recovery Plan 2008–2013. Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species at Risk Recovery Plan No. 15, Edmonton, Alberta, Canada.
- Apps, C. D. 1997. Identification of grizzly bear linkage zones along the Highway 3 corridor of southeast British Columbia and southwest Alberta. Ministry of Environment, Victoria, BC, and World Wildlife Fund Canada, Toronto, ON.
- Apps, C. D., J. L. Weaver, P. C. Paquet, B. Bateman, and B. N. McLellan. 2007. Carnivores in the southern Canadian Rockies: core areas and connectivity across the Crowsnest Highway. Wildlife Conservation Society Canada Conservation Report No. 3. Toronto, Ontario, Canada.
- Apps, C., D. Paetkau, S. Rochetta, A. Hamilton, B. Bateman, and B. McLellan. 2008. Grizzly bear population density and distribution in the southern Coast Ranges: Year 4 progress and data summary. Aspen Wildlife Research and Ministry of Environment, Victoria, British Columbia.

- Apps, C., D. Paetkau, B. McLellan, A. Hamilton, and B. Bateman. 2014. Grizzly bear population abundance, distribution, and connectivity across British Columbia's southern Coast Ranges. Version 2.2. Aspen Wildlife Research and Ministry of Environment, Victoria, British Columbia.
- Artelle, K. A., S. C. Anderson, A. B Cooper., P. C. Paquet, J. D. Reynolds, and C. T. Darimont. 2013. Confronting uncertainty in wildlife management: performance of grizzly bear management. *PlosOne* 8: e78041. doi:10.1371/journal.pone.0078041
- Austin, M. A., and A. N. Hamilton. 2004. A review of grizzly bear harvest management in British Columbia. B.C. Ministry of Environment. Victoria. B.C. https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/wildlife-wildlife-habitat/grizzly-bears/grizzly_harvest_review.pdf Accessed 27 January 2021.
- B.C. Conservation Strategy 1995. A future for the Grizzly: British Columbia Grizzly Bear Conservation Strategy. B.C. Ministry of Environment, Lands and Parks. Victoria. B.C. <https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/wildlife-wildlife-habitat/grizzly-bears/futureforgrizzly1995.pdf> Accessed 27 January 2021.
- B.C. Government Action Regulation. 2004. (B.C. Regulation 582/2004; General Wildlife Measures #8- 373), RD rule for grizzly bears for the Kettle–Granby GBPU.
- B.C. COS. 2020a. Human-grizzly bear (family unit) conflict response strategy). B.C. Conservation Officer Service, Victoria B.C. https://www2.gov.bc.ca/assets/gov/environment/natural-resource-policy-legislation/fish-and-wildlife-policy/response_guidelines_grizzly_bear_family_unit.pdf Accessed 27 January 2021.
- B.C. COS. 2020b. Human-grizzly bear (single) conflict response strategy). B.C. Conservation Officer Service, Victoria B.C. https://www2.gov.bc.ca/assets/gov/environment/natural-resource-policy-legislation/fish-and-wildlife-policy/response_guidelines_grizzly_bear_single.pdf Accessed 27 January 2021.
- B.C. Min. FLNRORD 2017. Outdoor Access Guide. RDEK Area, Fernie, Sparwood, Elkford. B.C. Min, of Forests, Lands, Natural Resource Operations and Rural Development. Cranbrook B.C. <http://www.env.gov.bc.ca/kootenay/eco/reports/Outdoor%20Access%20Guide%202017.pdf> Accessed 27 January 2021.
- B.C. Min. FLNRORD. 2020. British Columbia grizzly bear population estimate for 2018. B.C. Ministry of Forests, Lands, Natural Resource Operation, and Rural Development. Victoria, B.C. https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/wildlife-wildlife-habitat/grizzly-bears/grizzly_bear_pop_est_report_2018_final.pdf Accessed 27 January 2021.

- Benn, B., and S. Herrero. 2002. Grizzly bear mortality and human access in Banff and Yoho National Parks, 1971-98. *Ursus* 13:213-221.
- Boulanger, J. 2001. Analysis of the 1997 Elk Valley and Flathead Valley DNA mark-recapture grizzly bear inventory projects, 2001 revision. B.C. Ministry of Environment, Lands, and Parks, Victoria British Columbia.
- Boulanger, J., M. Cattet, S. E. Nielsen, G. Stenhouse, and Jerome Cranston. 2013. Use of multi-state models to explore relationships between changes in body condition, habitat and survival of grizzly bears *Ursus arctos horribilis*. *Wildlife Biology* 19:274–288.
- Boulanger, J., and G. B. Stenhouse. 2014. The impact of roads on the demography of grizzly bears in Alberta. *PlosOne* 9(12): e115535. Doi:10.1371/journal.pone.0115535.
- Braid, A. C. R., and S. E. Nielsen. 2015. Prioritizing sites for protection and restoration of grizzly bears in southwestern Alberta, Canada. *PLOS ONE* 10: e0132501.
- Chetkiewicz, C. L. B., and M. S. Boyce. 2009. Use of resource selection functions to identify conservation corridors. *Journal of Applied Ecology* 46:1036–1047.
- Clevenger, A., C. Apps, T. Lee, M. Quinn, D. Paton, D. Poulton, and R. Ament. 2010. Highway 3: Transportation mitigation for wildlife and connectivity in the crown of the continent ecosystem. https://www.rockies.ca/files/reports/H3%20Final%20Report%200607_June8.pdf Accessed 15 December 2020.
- COSEWIC. 2012. COSEWIC assessment and status report on the Grizzly Bear *Ursus arctos* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xiv + 84 pp. (www.registrelep.sararegistry.gc.ca/default_e.cfm). <https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports/grizzly-bear.html>. Accessed 26 January 2021.
- Costello, C. M., and L. Roberts. 2020. Northern Continental Divide Ecosystem grizzly bear population monitoring annual report, 2019. Montana Fish, Wildlife & Parks, Kalispell, Montana, USA.
- Farr, D., A. Braid, A. Janz, B. Sarchuk, S. Slater, A. Sztaba, G. Stenhouse, A. Morehouse, and M. Wheatley. 2017. Ecological response to human activities in southwestern Alberta: Scientific assessment and synthesis. Alberta Environment and Parks, Government of Alberta. ISBN No. 978-4601-350-2.
- Festa-Bianchet, M. 2010. Status of the grizzly bear (*Ursus arctos*) in Alberta: Update 2010. Alberta Sustainable Resource Development. Wildlife Status Report No. 37, Edmonton, Alberta, Canada.
- Ford, A. T., A. P. Clevenger, and K. Rettie. 2010. The Banff Wildlife Crossing Project: – An international public-private partnership. Pages 157-172 in *Safe passages: highways, wildlife*

- and habitat connectivity. J. Beckmann, A. P. Clevenger, M. Juijser, and J. Hilty (eds). Island Press, Washington D.C., USA.
- Garshelis, D. L., M. L. Gibeau, and S. Herrero. 2005. Grizzly bear demographics in and around Banff National Park and Kananaskis Country. *Journal of Wildlife Management* 69:277–297.
- Hamilton, A. N., and M. A. Austin. 2004. Grizzly bear harvest management in British Columbia: background report. B.C. Ministry of Environment, Lands and Parks. Victoria. B.C.
<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.396.1546&rep=rep1&type=pdf>
Accessed 27 January 2021.
- Hatter, I. W., G. Mowat, and B. N. McLellan. 2018. Statistical population reconstruction to evaluate grizzly bear trends in British Columbia, Canada. *Ursus* 29: 1-12.
- Hilderbrand, G. V., C. C. Schwartz, C. T. Robbins, M. E. Jacoby, T. A. Hanley, S. M. Arthur, and C. Servheen. 1999. The importance of meat, particularly salmon, to body size, population productivity, and conservation of North American brown bears. *Canadian Journal of Zoology* 77:132–138.
- Hilderbrand, G. V., D. D. Gustine, K. Joly, B. Mangipane, W. Leacock, M. D. Cameron, M. S. Sorum, L. Sl. Mangipane, and J. A. Eriénbach. 2019. Influence of maternal body size, condition, and age on recruitment of four brown bear populations. *Ursus* 29:111-118.
- Kasworm, W. F., T. G. Radandt, J. E. Teisberg, A. Welander, T. Vent, M. Proctor, H. Cooley, and J. Fortin-Noreus. 2020a. Selkirk Mountains grizzly bear recovery area 2019 research and monitoring progress report. U.S. Fish and Wildlife Service, Missoula, Montana.
<https://www.fws.gov/mountain-prairie/es/species/mammals/grizzly/Selkirk2019annualreport.pdf> Accessed 27 January 2021.
- Kasworm, W. F., J. E. Teisberg, T. Vent, A. Welander, M. Proctor, H. Cooley, and J. Fortin-Noreus. 2020b. Cabinet0Yaak grizzly bear recovery area 2019 research and monitoring progress report. U.S. Fish and Wildlife Service, Missoula, Montana.
<https://www.fws.gov/mountain-prairie/es/species/mammals/grizzly/CabYaak2019annualreport.pdf> Accessed 27 January 2021.
- Kendall, K. C., J. B. Stetz, J. Boulanger, A. C. Macleod, D. Paetkau, and G. C. White. 2009. Demography and genetic structure of a recovering grizzly bear population. *Journal of Wildlife Management* 73:3–17.
- Ladle, A. 2017. Grizzly bear response to linear features and human recreational activity. Dissertation, University of Alberta, Edmonton, Canada.
- Lamb C. T., G. Mowat, B. N. McLellan, S. E. Nielsen, and S. Boutin. 2016. Forbidden fruit: human settlement and abundant fruit create an ecological trap for an apex predator. *Journal of Applied Ecology* 86:55–65

- Lamb, C. T., G. Mowat, A. Reid, L. Smit, M. Proctor, B. N. McLellan, S. E. Nielsen, and S. Boutin. 2018. Effects of habitat quality and access management on the density of a recovering grizzly bear population. *Journal of Applied Ecology* 55:1406–1417.
- Lee, T., A. P. Clevenger, and C. Lamb. 2019. Amendment: Highway 3 transportation mitigation for wildlife and connectivity in the Elk Valley of British Columbia. Miistakis Institute. Mount Royal University, Calgary, AB.
- Mace, R. D., J. S. Waller, T. L. Manley, L. J. Lyon, and H. Zuring. 1996. Relationships among grizzly bears, roads, and habitat use in the Swan Mountains, Montana. *Journal of Applied Ecology* 33:1395–1404.
- Mace, R. D., D. W. Carney, T. Chilton-Radant, S. A. Courville, M. A. Haroldson, R. B. Harris, J. Jonkel, B. McLellan, M. Madel, T. L. Manley, C. C. Schwartz, C. Servheen, G. Stenhouse, J. S. Waller, and E. Wenum. 2012. Grizzly bear population vital rates and trend in the Northern Continental Divide Ecosystem, Montana. *Journal of Wildlife Management* 76:119–128.
- MacHutchon, A. G., and M. F. Proctor. 2016. Management Plan for the Yahk and South Selkirk Grizzly Bear (*Ursus arctos*) Sub-Populations, British Columbia. Trans-Border Grizzly Bear Project, Kaslo, B.C. 84 pp.
- McLellan, B. N., and D. M. Shackleton. 1988. Grizzly bears and resource-extraction industries: effects of roads on behaviour, habitat use, and demography. *Canadian Journal of Zoology* 25:451–460.
- McLellan, B. N. 1989a. Dynamics of a grizzly bear population during a period of industrial resource extraction. I. Density and age–sex composition. *Canadian Journal of Zoology* 67:1856–1860.
- McLellan, B. N. 1989b. Dynamics of a grizzly bear population during a period of industrial resource extraction. II. Mortality rates and causes of death. *Canadian Journal of Zoology* 67:1861–1864.
- McLellan, B. N. 1989c. Population dynamics of grizzly bears during a period of resource extraction development. III. Natality and rate of change. *Canadian Journal of Zoology* 67:1865–1868.
- McLellan, B. N. 1998. Maintaining viability of brown bears along the southern fringe of their distribution. *Ursus* 10:607–611.
- McLellan, B. N., F. W. Hovey, R. D. Mace, J. G. Woods, D. W. Carney, M. L. Gibeau, W. L. Wakkenen, and W. F. Kasworm. 1999. Rates and causes of grizzly bear mortality in the interior mountains of British Columbia, Alberta, Montana, Washington, and Idaho. *Journal of Wildlife Management* 63:911–920.

- McLellan, B. N. and F. W. Hovey. 1995. The diet of grizzly bears in the Flathead River drainage of southeastern British Columbia. *Canadian Journal of Zoology* 73:704–712.
- McLellan, B. N., and F. W. Hovey. 2001a. Habitats selected by grizzly bears in multiple use landscapes. *Journal of Wildlife Management* 65:92–99.
- McLellan, B. N., and F. W. Hovey. 2001b. Natal dispersal of grizzly bears. *Canadian Journal of Zoology* 79:838–844.
- McLellan, B. N. 2011. Implications of a high-energy and low-protein diet on the body composition, fitness, and competitive abilities of black (*Ursus americanus*) and grizzly (*Ursus arctos*) bears. *Canadian Journal of Zoology* 89:546–558.
- McLellan, B. N. 2015. Some mechanisms underlying variation on vital rates on grizzly bear in an industrial landscape. *Journal of Wildlife Management* 79:749–765.
- McLellan, B. N., G. Mowat, A. N. Hamilton, and I Hatter. 2017a. Sustainability of the grizzly bear hunt in British Columbia, Canada. *Journal of Wildlife Management* 81:218–229.
- McLellan, B. N., M. F. Proctor, D. Huber, D. and S. Michel. 2017b. *Ursus arctos* (amended version of 2017 assessment). *The IUCN Red List of Threatened Species* 2017: e.T41688A121229971. <https://www.iucnredlist.org/species/41688/121229971>. To access - click Population in Detail/Supplemental Information.
- McLellan, M. L. 2018. Habitat Connectivity Mapping between the Stein-Nahatlatch and Southern Chilcotin Grizzly Bear Populations. Conservation Northwest. Seattle, WA.
- McLellan, M. L., and B. N. McLellan. 2015. Effect of season and high ambient temperature on activity levels and patterns of grizzly bear (*Ursus arctos*). *PlosOne* 10: e0117734. doi:10.1371/journal.
- McLellan, M. L., B. N. McLellan, R. Sollmann, C. T. Lamb, C. D. Apps, and H. U. Wittmer. 2019. Divergent population trends following the cessation of legal grizzly bear hunting in southwestern British Columbia, Canada. *Biological Conservation* 233:247–254.
- McLellan, B. N., G. Mowat, and C. T. Lamb. 2018. Estimating unrecorded human-caused mortalities of grizzly bears in the Flathead valley, British Columbia, Canada. *PeerJ* 6:e5781; DOI 10.7717/peerj.5781.
- Miller, S. D. and J. Schoen. 1999. Status and management of the brown bear in Alaska. In *Bears: status survey and conservation action plan*, pp. 40–46. Eds. Servheen, C., Herrero, S. & Peyton, B. Gland: IUCN/SSC Bear and Polar Bear Specialist Groups, International Union for the Conservation of Nature.

- Miller, S. D., J. W. Schoen, and C. C. Schwartz. 2017. Trends in brown bear reduction efforts in Alaska, 1980–2017. *Ursus* 28:135–149.
- Morehouse, A. T., and M. S. Boyce. 2016. Grizzly bears without borders: spatially explicit capture-recapture in southwestern Alberta. *Journal of Wildlife Management* 80:1152–1166.
- Morehouse, A. T., and M. S. Boyce. 2017a. Troublemaking carnivores: conflicts with humans in a diverse assemblage of large carnivores. *Ecology and Society* 22:4
<https://doi.org/10.5751/ES-09415-220304>
- Morehouse, A. T., and M. S. Boyce. 2017b. Evaluation of intercept feeding to reduce livestock depredation by grizzly bears. *Ursus* 28:66–80.
- Morehouse, A. T., T. A. Graves, N. Mickle, and M. S. Boyce. 2016. Nature vs. Nurture: evidence for social learning of conflict behaviour in grizzly bears. *PLOS ONE* 11:e0165425.
- Morehouse, A. T., J. Tigner, and M. S. Boyce. 2018. Coexistence with large carnivores supported by a predator-compensation program. *Environmental Management* 61:719–731.
- Morehouse, A. T. 2018. Spatially explicit capture-recapture estimates of grizzly bear density and abundance in Alberta's Bear Management Area 5. Report prepared for Alberta Environment and Parks. https://www.watertonbiosphere.com/wp-content/uploads/2019/06/BMA-5-Report-FINAL-VERSION_11June18.pdf Accessed 15 December 2020.
- Morehouse, A. T., C. Hughes, N. Manners, J. Bectell, and T. Bruder. 2020. Carnivores and Communities: a case study of human-carnivore conflict mitigation in southwestern Alberta. *Frontiers in Ecology and Evolution*. <https://doi.org/10.3389/fevo.2020.00002>
- Morgan, D., M. Proctor, G. Mowat, B. McLellan, T. Hamilton, and L. Turney. 2020. Conservation ranking of grizzly bear population units – 2019. Ministry of Environment and Climate Change Strategy, Victoria. BC. 37pp. B.C. Ministry of Forests Lands and Natural Resource Operations. Victoria. B.C. https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/wildlife-wildlife-habitat/grizzly-bears/bc_gbpu_2019_ranking.pdf Accessed 27 January 2021.
- Mowat, G., and C. Strobeck. 2000. Estimating population size of grizzly bears using hair capture, DNA profiling, and mark-recapture analysis. *Journal of Wildlife Management* 64:183–193.
- Mowat, G., and C. T. Lamb. 2016. Population status of the South Rockies and Flathead grizzly bear populations in British Columbia, 2006-2014. B.C. Ministry of Forests Lands and Natural Resource Operations. Nelson, B.C.
https://www.researchgate.net/publication/302934739_Population_status_of_the_South_Rockies_and_Flathead_grizzly_bear_populations_in_British_Columbia_2006-2014/link/5735fe0608ae9f741b29ca91/download Accessed 27 January 2021.

- Mowat, G., M. Efford, B. McLellan, and S. Nielsen. 2013. South Rockies & Flathead grizzly bear monitoring final report 2006-2011. B.C. Ministry of Forests Lands and Natural Resource Operations. Nelson, B.C.
https://www.researchgate.net/publication/322687150_South_Rockies_Flathead_Grizzly_Bear_Monitoring_Final_Report_2006-2011 Accessed 27 January 2021.
- Mowat, G., D. C. Heard and C. J. Schwarz. 2013. Predicting grizzly bear density in western North America. *PLoS One*. 8(12): e82757.
- Nielsen, S. E., J. Cranston, and G. B. Stenhouse. 2009. Identification of priority areas for grizzly bear conservation and recovery in Alberta, Canada. *Journal of Conservation Planning* 5:38–60.
- Nielsen, S. E., S. Herrero, M. S. Boyce, R. D. Mace, B. Benn, M. L. Gibeau, and S. Jevons. 2004. Modelling the spatial distribution of human-caused grizzly bear mortalities in the Central Rockies Ecosystem of Canada. *Biological Conservation* 120:101–113.
- North Cascades Grizzly Bear Recovery Team. 2004. Recovery plan for grizzly bears in the North Cascades of British Columbia. B.C. Ministry of Environment. Victoria, B.C.
http://www.env.gov.bc.ca/wld/documents/recovery/ncgb_rp0101.pdf Accessed 27 January 2021.
- Northrup, J. M., J. Pitt, T. B. Muhly, G. B. Stenhouse, M. Musiani, and M. S. Boyce. 2012a. Vehicle traffic shapes grizzly bear behaviour on a multiple-use landscape. *Journal of Applied Ecology* 49:1159–1167.
- Northrup, J. M., G. B. Stenhouse, and M. S. Boyce. 2012b. Agricultural lands as ecological traps for grizzly bears. *Animal Conservation* 15:369–377.
- OAG 2017. An independent audit of grizzly bear management. Office of the Auditor General of British Columbia Victoria, B.C.
https://www.bcauditor.com/sites/default/files/publications/reports/FINAL_Grizzly_Bear_Management.pdf Accessed 27 January 2021.
- Paetkau, D. H., G. F. Shields, and C. Strobeck. 1998a. Gene flow between insular, coastal and interior populations of brown bears in Alaska. *Molecular Ecology* 7:1283-1292.
- Paetkau, D., L. P. Waits, P. L. Clarkson, L. Craighead, E. Vyse, R. Ward, and C. Strobeck. 1998b. Variation in genetic diversity across the range of North American brown bears. *Conservation Biology* 12:418-429.
- Peek, J., J. Beecham, D. Garshelis, S. Miller, and D. Strickland. 2003. Management of grizzly bears in British Columbia: A review by an independent scientific panel. B.C. Ministry of Water, Lands and Air Protection. Government of British Columbia, Victoria, B.C.

- Peek, J. M., M. R. Pelton, H. D. Picton, J. W. Schoen, and P. Zager. 1987. Grizzly bear conservation and management: a review. *Wildlife Society Bulletin* 15:160–169.
- Peirce, K. N., and L. J. Van Daele. 2006. Use of a garbage dump by brown bears in Dillingham, Alaska. *Ursus* 17:165-177.
- Proctor, M. 1995. DNA fingerprints from black bear hair as a basis for mark-recapture population estimation. Directed studies in ecology. University College of the Okanagan, Kelowna, British Columbia, Canada.
- Proctor, M., B.N. McLellan, C. Strobeck, and R. Barclay. 2005. Genetic analysis reveals demographic fragmentation of grizzly bears yielding vulnerably small populations. *Proceedings of the Royal Society, London* 272:2409–2416.
- Proctor, M., J. Boulanger, S. Nielsen, C. Servheen, W. Kasworm, T. Radandt and D. Paetkau. 2007. Abundance and density of Central Purcell, South Purcell, Yaak, and south Selkirk grizzly bear population units in southeast British Columbia. British Columbia Ministry of Environment, Nelson, B.C.
- Proctor, M.F, B.N. McLellan, J. Boulanger, C. Apps, G. Mowat, D. Paetkau, and G. Stenhouse. 2010. Ecological investigations of Canadian grizzly bears using hair-snagged DNA, 1995-2005. *Ursus*. 21:169-188.
- Proctor, M. F., D. Paetkau, B. N. McLellan, G. B. Stenhouse, K. C. Kendall, R. D. Mace, W. F. Kasworm, C. Servheen, C. L. Lausen, M. L. Gibeau, W. L. Wakkinen, M. A. Haroldson, G. Mowat, C. D. Apps, L. M. Ciarniello, R. M. R. Barclay, M. S. Boyce, C. C. Schwartz, and C. Strobeck. 2012. Population fragmentation and inter-ecosystem movements of grizzly bears in western Canada and the northern United States. *Wildlife Monographs* 180:1–46.
- Proctor, M. F., S. E. Nielsen, W. F. Kasworm, C. Servheen, T. G. Radandt, A. G. MacHutchon, and M. S. Boyce. 2015. Grizzly bear connectivity mapping in the Canada-US trans-border region. *Journal of Wildlife Management* 79:554–55.
- Proctor, M. F., W. F. Kasworm, K. M. Annis, A. G. MacHutchon, J. E. Teisberg, T. G. Radandt, C. Servheen. 2018. Conservation of threatened Canada-USA trans-border grizzly bears linked to comprehensive conflict reduction. *Human Wildlife Interactions* 12:248–272.
- Proctor, M. F., B. N. McLellan, G. B. Stenhouse, G. Mowat, C. T. Lamb, and M. Boyce. 2020. The effects of roads and motorized human access on grizzly bear populations in British Columbia and Alberta, Canada. *Ursus* 30e2:6–19.
- Proctor, M. F., T. Dutta, B N. McLellan, S. Garica-Rangel, D. Paetkau, R. R. Swaisgood, and A. Zedrosser. 2021a. Managing for interpopulation connectivity of the World’s Bear Species. In Eds. V. Penteriani and M. Melletti, *Bears of the World, Ecology, Conservation and Management* (pp. 317-337). Cambridge University Press. Cambridge, U.K.

- Proctor, M. F., C. T. Lamb, J. Boulanger, A. G. MacHutchon, W; F. Kasworm, D. Paetkau, M. Boyce, and C. Servheen. 2021b. The dance of berries and bullets: the influence of food resources and mortality risk on grizzly bear population in southeastern British Columbia. In review.
- Rausch, R. L. 1963. Geographic variation in size of North American brown bears, *Ursus arctos* L., as indicated by condylobasal length. Canadian Journal of Zoology 41:33–45.
- Roever, C. L., M. S., and G. B. Stenhouse. 2008. Grizzly bears and foresty I: Road vegetation and placement as an attractant to grizzly bears. Forest Ecology and Management 256:1253–1261.
- Roever, C. L., M. S. Boyce, and G. B. Stenhouse. 2010. Grizzly bear movements relative to roads: application of step selection functions. Ecography 33:1113–1122.
- SARA 2018. Species at Risk Public Registry. https://wildlife-species.canada.ca/species-riskregistry/species/speciesDetails_e.cfm?sid=1195. Accessed 27 January 2021.
- Sawaya, M. A., S. T. Kalinowski, and A. P. Clevenger. 2014. Genetic connectivity for two bear species at wildlife crossing structures in Banff National Park. Proceedings of the Royal Society B 281: <https://doi.org/10.1098/rspb.2013.1705>
- Schwartz, C. C., M. A. Haroldson, and G. C. White. 2010. Hazards affecting grizzly bear survival in the Greater Yellowstone Ecosystem. Journal of Wildlife Management 74:654–667.
- Schwartz, C. C., M. A. Haroldson, G. C. White, R. B. Harris, S. Cherry, K. A. Keating, D. Moody, and C. Servheen. 2006. Temporal, spatial, and environmental influences on the demographics of grizzly bears in the Greater Yellowstone Ecosystem. Wildlife Monographs 161:1–68.
- St. Clair, C. C., J. Whittington, A. Forshner, A. Gangadharan, and D. N. Laskin. 2020. Railway mortality for several mammal species increases with train speed, proximity to water, and track curvature. Scientific Reports 10: <https://doi.org/10.1038/s41598-020-77321-6>
- Statistics Canada. 2006. 2006 Community profiles: Pincher Creek No. 9, Municipal district. www.statcan.gc.ca.
- Stenhouse, G. B., J. Boulanger, M. Efford, S. Rovang, T. McKay, A. Sorensen, and K. Graham. 2015. 67 . Report prepared for Weyerhaeuser Ltd., West Fraser Mills Ltd, Alberta Environment and Parks, and Jasper National Park.
- Talbot, S. L., and G. F. Shields. 1996. Phylogeography of brown bears (*Ursus arctos*) of Alaska and Paraphyly within Ursidae. Molecular Phylogenetics and Evolution 5:477–494.

- U.S. Fish and Wildlife Service. 1993. Grizzly bear recovery plan. U.S. Fish and Wildlife Service, Missoula, Montana.
- U.S. Fish and Wildlife Service. 2020. Grizzly bear recovery program, 2020. Annual report. Grizzly Bear Recovery Program, U.S. Fish and Wildlife Service. University of Montana, Missoula, Mt. https://www.fws.gov/mountain-prairie/es/species/mammals/grizzly/2019%20GB%20Annual%20Report_Final.pdf Accessed 27 January 2021.
- Woods, J. G., D. Paetkau, D. Lewis, B. N. McLellan, M. Proctor, and C. Strobeck. 1999. Genetic tagging free-ranging black and brown bears. *Wildlife Society Bulletin*. 27:616–627.
- Yukon Grizzly Bear Conservation and Management Plan Working Group. 2019. A conservation plan for grizzly bears (*Ursus arctos*) in Yukon. Government of Yukon, Department of Environment, Whitehorse, Yukon.