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RECOVERY POTENTIAL ASSESSMENT OF BULL TROUT, *Salvelinus confluentus* (SASKATCHEWAN–NELSON RIVERS POPULATIONS)

Bull Trout, Salvelinus confluentus *© J.R. Tomelleri*

Figure 1. Distribution of Bull Trout in Designatable Unit 4, Saskatchewan–Nelson rivers populations.

Context:

*Bull Trout (*Salvelinus confluentus*) is a large freshwater char native to western Canada and the Pacific Northwest region of the United States. In November 2012, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated Bull Trout, Saskatchewan – Nelson rivers, Designatable Unit (DU) 4, as Threatened. Within this DU the range of the species has contracted and populations are now limited to the foothills and east slopes of the Rocky Mountains likely in response to habitat deterioration and reduced habitat connectivity through damming of the larger rivers. No populations are abundant and more than half show evidence of decline.*

DU 4 Bull Trout is being considered for legal listing under the Species at Risk Act *(SARA). In advance of making a listing decision, Fisheries and Oceans Canada (DFO) Science has been asked to undertake a Recovery Potential Assessment (RPA). This RPA summarizes the current understanding of the distribution, abundance and population trends of Bull Trout in DU 4, along with recovery targets and times. The current state of knowledge about habitat requirements, threats to both habitat and Bull Trout, and measures to mitigate these impacts for DU 4 are also included. This information may be* *used to inform both scientific and socio-economic elements of the listing decision, development of a recovery strategy and action plan, and to support decision-making with regards to the issuance of permits, agreements and related conditions, as per sections 73, 74, 75, 77 and 78 of SARA.*

This Science Advisory Report is from the June 15, 2016 Recovery Potential Assessment of Bull Trout, Salvelinus confluentus *(Saskatchewan – Nelson rivers populations). Additional publications from this meeting are posted on the DFO Science Advisory Schedule.*

SUMMARY

- In Alberta, the range of the Saskatchewan – Nelson rivers populations of Bull Trout within the basins of the Oldman, Bow, Red Deer, and North Saskatchewan rivers has contracted to the foothills and east slopes of the Rocky Mountains.
- Many of the Bull Trout populations have been declining over the past century. The total number of adults in all populations in this Designatable Unit is between 6,359 and 21,700 total mature individuals, with individual population estimates ranging from 10 to 1,275 mature individuals.
- In Alberta, there are three Bull Trout life history types; stream residents, fluvial (residing in larger free-flowing streams or rivers as adults, returning to headwater streams to spawn) and adfluvial (residing in lakes as adults, returning to headwater streams to spawn).
- The status of most of the Bull Trout populations in DU 4 is Poor. Bull Trout have been extirpated from seven HUCs (hierarchical hydrological units within watershed boundaries). Population status is Good in three HUCs, Fair in three HUCs and Poor in the remaining 32 HUCs.
- Habitat occupied by Bull Trout is characterized as cold, clean, complex and connected. Groundwater upwellings are an important component of Bull Trout habitat for all life history types.
- Redds created by females for spawning and the initial development of eggs and alevins meet the SARA definition of residence.
- The greatest threats to the long-term survival and recovery of Bull Trout in DU 4 are related to habitat fragmentation, habitat removal and alteration, competition from introduced salmonids, mortality related to fishing, climate change, in addition to the interactive and cumulative effects of these threats.
- Activities that have a moderate or higher probability of jeopardizing survival or recovery include in-water works (e.g., watercourse crossing, shoreline and streambank modifications, construction of barriers), linear development, forestry development, mineral aggregate and hydrocarbon exploration, extraction, and production, water management activities, and urban development.
- The dynamics of Bull Trout populations are particularly sensitive to perturbations that affect survival of immature individuals. Harm to these portions of the life cycle should be minimized to avoid jeopardizing the survival and future recovery of Saskatchewan – Nelson rivers populations.
- Demographic sustainability (i.e., a self-sustaining population over the long term) was used as a criterion to identify recovery targets for Bull Trout. Under conditions with a 15% chance of catastrophic mortality event per generation and a quasi-extinction threshold of 50 adults, abundance needs to be at least 1.9 million adult Bull Trout, requiring 510 km^2 of suitable habitat. Targets for alternative risk scenarios ranged from about 95 adults to about 10 million

adults and about 14,000 m^2 to about 4,300 km^2 of suitable habitat, respectively. Estimates are highly sensitive to the extinction threshold, the probability of catastrophic mortality, and the ratio of individuals from small and large-bodied growth trajectories in the population.

- A number of key sources of uncertainty exist for this species related to life history parameters, population connectivity and abundance estimates, the quantity and quality of available habitat and the potential impacts of threat mitigations.

INTRODUCTION

Rationale for Assessment

In November 2012, COSEWIC first assessed the Saskatchewan – Nelson rivers populations (DU 4) of Bull Trout as Threatened (COSEWIC 2012).

When COSEWIC designates a species as Threatened or Endangered, the Minister of Fisheries and Oceans (DFO) is required by the *Species at Risk Act* (SARA) to undertake a number of actions. Many of these actions require scientific information such as the current status of the population, the threats to its survival and recovery, and the feasibility of its recovery. This scientific advice is developed through a Recovery Potential Assessment (RPA). This allows for the consideration of peer-reviewed scientific analyses in subsequent SARA processes, including recovery planning and issuance of SARA permits.

The RPA for Bull Trout was held over two meetings, June 4–5, 2014 and June 15, 2016. Two research documents, that provide technical details and the full list of cited material, were reviewed during the meetings. One of the research documents provides background information on the species biology, habitat preferences, current status, threats and mitigations and alternatives (Sawatzky 2016), and the other on allowable harm, population-based recovery targets, and habitat targets (Caskenette et al. 2016). The proceedings report summarizes the key discussions of the meetings (DFO 2017). This science advisory report summarizes the main conclusions and advice from the science peer review.

Species Biology and Ecology

Bull Trout is a long and slender salmonid with a relatively large head and jaws. Pale, round spots on their back and sides and the absence of black markings on their dorsal fin are primary features distinguishing Bull Trout from co-occurring salmonids such as Rainbow Trout (*Oncorhynchus mykiss*), Cutthroat Trout (*O. clarkii*), Brown Trout (*Salmo trutta*), and Brook Trout (*Salvelinus fontinalis*).

In Alberta, there are three life history strategies exhibited by Bull Trout, resident (inhabiting headwaters of streams), fluvial (residing in larger free-flowing streams or rivers as adults, returning to headwater streams to spawn) and adfluvial (residing in lakes as adults, returning to headwater streams to spawn). Body size at maturity varies by life history type with the resident form having an average size at maturity of 250 mm fork length (FL) (range 150–300 mm FL), fluvial > 400 mm FL (range 240–730 mm FL), and adfluvial > 400 mm FL (range 330–900+ mm FL). Occurrence of the three life history types are summarized by waterbody in the Appendix (Table A1).

Bull Trout typically reach sexual maturity between age 5–7 (range 3–8 years). Ages up to 24 years have been documented, but maximum age is unknown. Generation time has been estimated at approximately 7 years in mixed life history populations in British Columbia. The sex ratio of populations is typically 1:1. Fecundity is related to body size, small, resident females produce approximately 500 eggs and larger, migratory females produce 2,000–5,000 eggs.

Bull Trout is iteroparous but may spawn in alternate years. Spawning occurs from mid-August to late October. Resident Bull Trout spawn locally, but migratory forms may migrate over 200 km to spawn and generally exhibit homing to natal streams although straying within localized areas has been documented. Spawning migrations begin between late May and August depending on distance to be travelled, with movements generally occurring at night. Spawning usually occurs during the day but may occur at night in disturbed systems and has been documented to occur at temperatures below 10 °C and is suspended below approximately 5 °C.

Bull Trout are opportunistic predators, consuming a variety of vertebrate and invertebrate prey, altering their diet based on prey availability. Prey species vary across their range, but the general taxonomic groups that make up their diet include annelids, molluscs, crustaceans, insects, fish, amphibians, birds and small mammals. Juveniles forage on drift during the day and benthic organisms at night, rarely if ever feeding at the surface. Mayflies, midges, stoneflies and caddisflies form the bulk of the diet in both lakes and streams during the summer but when juveniles reached 100–200 mm in length they begin to prey on fish. The adult diet includes invertebrates, but as Bull Trout grow, fishes, when available, become more important in their diet. In the Elbow River, Alberta adult Bull Trout fed almost exclusively on fish including Brook Trout, Cutthroat Trout, Mountain Whitefish (*Prosopium williamsoni*), Rainbow Trout and juvenile Bull Trout. The diet of larger Bull Trout may also include frogs, snakes, ducklings and small mammals. Dietary differences between resident and migratory forms are likely related to prey availability in habitats occupied and to some extent may be responsible for resident Bull Trout being much smaller than fluvial fish, which in turn, are smaller than adfluvial fish.

The physiological requirements of Bull Trout, most notably water temperature, limit its distribution. A narrow range of cold water temperatures is required for reproduction and survival. Adults generally occur in water below 18 °C, but are more common at temperatures below 12 °C. Colder temperatures are especially important during incubation and juvenile rearing. The optimal incubation temperature range is 2–4 °C with survival declining rapidly at temperatures above 8 °C. Groundwater inflows are important in maintaining stable temperatures during egg incubation. Bull Trout do exhibit a high degree of behavioural thermoregulation and are able to forage in waters with higher than preferred temperatures.

Growth patterns, stage-specific annual mortality, and fecundity-at-stage of Bull Trout were determined using data and estimates from the literature (Caskenette et al. 2016). DU 4 Bull Trout exhibit one or more of the three life-history types, resulting in a variety of growth trajectories including fish that remain small through their complete lifecycle, fish that grow to large sizes, or a combination of both large and small growth trajectories. Table 1 summarises the range of values for life-history parameters used to model Bull Trout with small, large and mixed trajectory growth curves.

The range of parameter values used in the modelling (Table 1) are based on the best information available. Models would need to consider the different Bull Trout life history types.

Table 1. Range of values and descriptions for parameters used to model Bull Trout with small, large and mixed trajectory growth curves. See Caskenette et al. 2016 for source detail.

	Description	Estimate		
		Small	**Large**	**Mixed**
Growth	Asymptotic size (mm)	326–361	768–844	325–850
	Growth coefficient	0.14–0.17	0.12–0.14	0.12–0.17
	Age at 0 mm	-0.21–0.01	0.17–0.32	-0.21–0.31
Survival	Instantaneous mortality at unit size	22–140	161–353	97–350
	Young-of-year (YOY)	0.01–0.55	0.05–0.25	0.05–0.09
	Juvenile Stages (1–4)	0.15–0.92	0.05–0.75	0.09–0.73
	Adult Stage	0.62–0.95	0.59–0.78	0.48–0.76
Fecundity	Proportion female	0.5		
	Spawning periodicity	1–2		
	Fertility (egg count)	0–8,000		
	Proportion reproductive	J = 0, A = 1		
Age	Maximum age	9.01–12.77		
	Age at maturity	5.62–8.51		
Matrix	Effective fecundity	196–252	1691–2145	195–2144
	Probability of transitioning	0.10–0.30	0.05–0.16	0.04–0.21
	Proportion in small trajectory	NA		0.5
Analysis	Annual population growth rate	various		
	Maximum growth rate	1.8	1.3	1.4

ASSESSMENT

Historic and Current Distribution and Trends

Bull Trout is endemic to northwestern North America occupying a large geographic range. The species is distributed from the Oregon-California border and northern Nevada (42°N) to southern Yukon and southwestern Northwest Territories (65°N) and extends from the Pacific Coast in southwestern British Columbia and northwestern Washington (~ 113°W) in the west, to the eastern slope of the continental divide in western Montana and Alberta and the Northwest Territories in the east. The range has declined over the past century, particularly the southern extent in the U.S.

Approximately 80% of its global range is within western Canada (British Columbia, Alberta, Yukon and Northwest Territories). Within Alberta, the range includes all of the major east slope river drainages; Peace, Athabasca, South Saskatchewan and North Saskatchewan. Historically, Bull Trout were more widely distributed in Alberta. Once occupying reaches further downstream, they are now restricted to upstream reaches with the exception of the northern Peace and Athabasca drainages where they occur in low abundance. In recent decades, Bull Trout's distribution has also declined in eastern parts of its range in Alberta.

The distribution of Bull Trout in DU 4 extends from the North Saskatchewan River south to the Canada-USA border. The extent of occurrence is estimated to be greater than 20,000 km^2 and the index of area of occupancy greater than 2,000 km^2. Occupancy estimated for waterbodies are included in the Appendix (Table A1).

Within DU 4, Bull Trout occur in four river basins, the Oldman, Bow, Red Deer and North Saskatchewan. Bull Trout are no longer found in large areas of the Oldman River drainage and the Red Deer River system. Once abundant in the North Saskatchewan River near Edmonton, they have not been documented there since the late 1950s.

Historic and Current Abundance and Trends

Alberta Sustainable Resource Development has assessed the status of their Bull Trout populations within spatial units (Figure 1) based on 8-digit Hydrologic Unit Codes (HUC8). HUCs are a series of hierarchical hydrological units within watershed boundary dataset. A total of 88 Bull Trout HUCs were delineated within Alberta, 45 of which are in DU 4. Several metrics were examined to assess the stocks within the HUCs, including metrics of population integrity, productive potential and threat mitigation as part of the Alberta Fish Sustainability Index (FSI).

The populations of Bull Trout in DU 4 were ranked in terms of their abundance (Relative Abundance Index) using the FSI and trajectory (Population Trajectory). These were then combined to determine the population status (Table 2) for each HUC8. The Relative Abundance Index was assigned as Extirpated, Low, Medium, High or Unknown. The population trajectory was assessed as Increasing (an increase in abundance over time), Stable (no change in abundance over time), Decreasing (a decrease in abundance over time) or Unknown. The overall population status was categorized as Poor, Fair, Good, Unknown or Extirpated. Current abundance estimates for waterbodies (and corresponding HUCs) are included in the Appendix (Table A1).

Table 2. Relative Abundance Index using the Alberta Fish Sustainability Index and Population Trajectory of Bull Trout for HUCs within DU 4.

Oldman River Basin

HUC	Relative Abundance Index	Population Trajectory	Population Status
04010101	Low	Decreasing	Poor
04010102	Low	Decreasing	Poor
04010103	Medium	Decreasing	Poor
04010104	Low	Stable	Poor
04010105	Low	Decreasing	Poor
04010201	Extirpated	n/a	Extirpated
04010301	Low	Decreasing	Poor
04010302	Low	Decreasing	Poor
04010401	Low	Decreasing	Poor

Bow River Basin

HUC	Relative Abundance Index	Population Trajectory	Population Status
04020101	Medium	Decreasing	Poor
04020201	Low	Decreasing	Poor

HUC	Relative Abundance Index	Population Trajectory	Population Status
04020301	Low	Decreasing	Poor
04020501	High	Stable	Good
04020401	Low	Decreasing	Poor
04020601	Low	Decreasing	Poor
04020701	Medium	Stable	Fair
04020801	Extirpated	n/a	Extirpated
04020802	Low	Decreasing	Poor
04021001	Low	Decreasing	Poor
04021101	Extirpated	n/a	Extirpated
04021201	Low	Decreasing	Poor
04021202	Low	Decreasing	Poor

Red Deer River Basin

HUC	Relative Abundance Index	Population Trajectory	Population Status
08010101	Low	Decreasing	Poor
08010102	Low	Decreasing	Poor
08010103	Low	Decreasing	Poor
08010104	Low	Decreasing	Poor
08010201	Low	Decreasing	Poor
08010202	Extirpated	n/a	Extirpated
08010203	Low	Decreasing	Poor

North Saskatchewan River Basin

HUC	Relative Abundance Index	Population Trajectory	Population Status
11010101	High	Stable	Good
11010102	Medium	Stable	Fair
11010103	High	Stable	Good
11010201	Low	Decreasing	Poor
11010202	Medium	Stable	Fair
11010203	Low	Decreasing	Poor
11010301	Medium	Decreasing	Poor
11010302	Low	Decreasing	Poor
11010401	Medium	Decreasing	Poor
11010402	Low	Decreasing	Poor
11010403	Medium	Decreasing	Poor
11010404	Low	Decreasing	Poor
11010405	Extirpated	n/a	Extirpated
11010406	Medium	Decreasing	Poor

HUC	Relative Abundance Index	Population Trajectory	Population Status
11020101	Extirpated	n/a	Extirpated
11020102	Extirpated	n/a	Extirpated

Habitat Requirements

Bull Trout habitat is generally described as cold, clean, complex and connected. Seasonal and perennial groundwater upwellings are an important component of Bull Trout habitat for all life history types.

Resident Life History

Stream Resident Bull Trout live permanently in the small, cold spawning tributary streams and often spawn and overwinter within a 2 km section of river. They are strongly associated with pool habitat and instream and overhead cover. They may be connected to migrant populations or be fully or partially isolated by natural barriers. In the West Castle River (Oldman River basin) resident juveniles and adults overwinter in small, shallow pools with a maximum depth of 0.4–1.5 m. These pools are isolated from one another, provide little cover and receive flow from perennial groundwater springs. Seasonal groundwater upwellings provide residents with cold-water refugia in summer and perennial groundwater upwellings provide warm-water refugia in winter. Stream resident Bull Trout are active during the night throughout the winter on or above the substrate, even during extreme temperature and ice conditions. Small fish (< 200 mm) seek cover in course substrates and large woody debris.

Fluvial Life History

Fluvial populations occupy rivers and major tributaries and move into high gradient smaller rivers and tributary streams to spawn. In addition to spawning habitat, these smaller rivers and streams also provide rearing habitat for young-of-year and young juveniles. Spawning in the mainstems of the rivers and major tributaries occupied by older juveniles and adults has not been documented although suitable spawning habitat may exist and spawning could be possible in these rivers. Fluvial adults may undertake extensive seasonal migrations, typically upstream to spawning tributaries in May to August and downstream to overwintering areas by late September to early October. These migrations may be lengthy (up to 500 km) and demonstrate the spatial scale and habitat diversity required by fluvial populations, the importance of high quality spawning habitat and the importance of stream connectivity.

The onset of spawning migrations may be triggered by declining water temperature and shortening day lengths but varies among rivers. The spawning migration may begin early for fish that migrate long distances and gain elevation, or that migrate through systems with low flow or unfavourable temperature conditions. In the upper North Saskatchewan River area, return migrations to overwintering areas occurred from September to the end of October and were completed by early December. Return migrations may be triggered by declining water temperature and low stream flows. In some systems, fluvial Bull Trout exhibit a strong fidelity to spawning tributaries and overwintering areas, but in others they change spawning locations over time. Movements during the winter are typically minimal.

Adfluvial Life History

Adfluvial Bull Trout reside in lakes and move into high gradient small rivers and tributary streams to spawn. Spawning within lakes has not been documented. Juvenile rearing begins in the spawning stream. They eventually move downstream into large rivers or lakes to feed, mature and overwinter. Larger adults more often feed and overwinter in lakes. Spawning migration distance varies depending on the availability and location of suitable spawning habitat.

In high, isolated oligotrophic lakes (e.g., Pinto and Harrison lakes, Alberta) spawning habitat is usually located a short distance upstream in the lake inlet or downstream in the outlet. Habitat use within lakes shifts with the season and changing water temperatures. Bull Trout are generally more evenly distributed under isothermal conditions, but seek cooler, deeper water in the summer. They typically rest near the substrate during the day and forage in the littoral zone at night.

Spawning and Incubation Habitat

High quality spawning habitat and access to it (i.e., connectivity) is essential for maintaining healthy populations of Bull Trout. Successful incubation depends upon temperature, gravel composition, permeability and surface flow. Spawning streams are typically high elevation, structurally complex, shallow headwater or tributary streams with stable channels. The structural complexity ensures habitat for both spawning adults and rearing juveniles.

Adults undergo a behavioural shift in habitat use once in the natal stream (after migration for fluvial and adfluvial Bull Trout) towards a pattern of seeking cover during the day in woody debris and substrate crevices and emerging at night. They spawn in flowing water in coarse gravel-cobble substrates with low levels of fine sediment. In experimental studies, hatching success was found to be inversely related to percent fine material (< 6.35 mm). Survival to emergence ranged from 49–69% in substrates with 10% fines to 0–4% in substrates with 50% fines.

Redds are typically constructed at sites associated with perennial groundwater upwellings, an important component of Bull Trout spawning habitat. Eggs incubate over the winter and are thus vulnerable to sediment accumulation, anchor ice accumulations, scouring, low flows and freezing. Groundwater upwellings stabilise temperatures through the winter, provide stable flows and prevent anchor and frazil ice formation. Within these areas of upwelling, they often select localized spots of strong downwelling and high intergravel flows, increasing aeration of eggs. Water above redds and in the interstitial spaces is well oxygenated (e.g., 10–11.5 mg/L and 8–12 mg/L, respectively). Water velocities at spawning sites range from 2–92 cm/s and depths from 0.07–0.93 m. The area disturbed by redd construction varies from 0.5–3.72 m^2. Larger female spawners can bury eggs deeper in coarser substrates, closer to the center of the channel reducing the likelihood of freezing or desiccation. In Dutch Creek (Oldman River drainage), the majority of redds were located in gravel substrate under woody debris, overhanging vegetation or undercut banks. Overhead cover has been found to be important in some areas of Bull Trout distribution.

Fry and Young Juvenile Rearing Habitat

Eggs hatch in late spring and yolk absorption takes 65 to 90 days. Neutral buoyancy is attained three weeks after yolk absorption is complete. Negative buoyancy at emergence makes feeding difficult but allows fry to maintain their position within the stream. At this stage, fry are typically found in shallow, low-velocity stream margins with an abundance of cover and coarse cobble-boulder substrate. Once they are neutrally buoyant, fry exhibit diel habitat shifts – the majority are generally out of cover from late morning to early evening and return to cover about two hours before dusk.

As they grow they typically move to deeper, faster-flowing water and prefer pools over riffles. Microhabitat use of young juveniles shifts daily and seasonally. They remain near cover during the day, dispersing at night. This pattern is common during all seasons but is particularly evident in winter. In laboratory studies, age 1 Bull Trout preferred cobble and boulder substrate during the day and silt and gravel at night; shallower, lower velocity water was also preferred during the day. Similar habitat use has been observed in the wild. In fall, young juveniles generally move to deeper, low velocity areas with coarse substrates where they remain near the substrate and close to cover. Shade, undercut banks and large woody debris are used for cover where available. These habitat features are less common at higher latitudes and/or elevations so pocket pools, root wads, cobbles, boulders and overhanging vegetation are used instead. In the West Castle River drainage, young-of-year overwinter within and upstream of the spawning area in interstitial sub-surface flow under the dry channel bed.

Older Juvenile and Adult Foraging and Overwintering Habitat

Juveniles move out of rearing streams into larger rivers generally by age 3–4, but in Alberta they may stay in rearing areas for up to six years. As they grow larger than 100 mm total length, juveniles become less associated with the substrate but remain near cover. In rivers, older juveniles and adults prefer low-velocity water, are often associated with the tail-outs of pools and remain near cover. Groundwater upwellings and overhead and/or instream cover are important components of overwintering habitat. In lakes, Bull Trout are generally more abundant in deeper, cooler water. They typically rest on the bottom during the day and move into the littoral zone to forage at night.

Functions, Features and Attributes

Table 3 describes the functions, features and attributes associated with Bull Trout habitat. The habitat required for each life stage of Bull Trout has been assigned a function that corresponds to a biological requirement and features considered the structural component of the habitat necessary for the survival or recovery of the species. Habitat attributes have also been provided, which describe how the features support the function for each life stage. Habitat attributes associated with current records may differ from optimal habitat as Bull Trout may be occupying sub-optimal habitat where optimal habitat is not available.

There are no data to quantify how the biological functions that specific habitat features provide vary with the state or amount of habitat, including carrying capacity limits.

The spatial extents of spawning, rearing, foraging and overwintering habitat have not been quantified for Bull Trout in DU 4. Sawatzky (2016) describes spawning and overwintering habitat identified in each river basin. Redds are often concentrated in specific areas even though larger areas of suitable habitat appear to be available. This can be so pronounced in some systems that a high degree of redd superimposition occurs.

Residence

Bull Trout redds meet the SARA definition of a residence. During spawning, female Bull Trout excavate a nest, or redd by turning on their side, arching their body and forcefully beating their caudal fin. Males position themselves alongside the female in the red where eggs and sperm are released and the fertilized eggs fall into the depression created by the female. The female deposits eggs over several spawning events, each time moving upstream and digging an area, displacing gravel that covers eggs downstream. Redds are typically excavated to a depth of 10–20 cm and may range from 40–350 cm in length and 15–200 cm in width. Spawning occurs from mid-August to late October. Over winter, the eggs remain in the substrate hatching into alevins between March and April. The length of incubation depends on the water temperature and varies from 100–200 days.

Table 3. Summary of the essential functions, features and attributes for each life stage of Bull Trout. Modified from Stewart et al. (2007). See Sawatzky (2016) for the full list of citations.

Life Stage	Function	Feature(s)	Attributes (Observed)	For Identification of Critical Habitat (Inferred)
Spawning / Incubation	Reproduction	• Interstices of bottom substrate in small tributary streams; redds are often constructed in areas with perennial groundwater upwellings	• High gradient streams • Spawning depth range: 0.07–0.93 m • Incubation depth range: 0.1–0.2 m • Substrate: gravel/cobble dominated substrate • Substrate size: 0–200 mm • Cover: overhanging vegetation, undercut banks, large woody debris, rootwads, but overhead cover is not a prerequisite for spawning; redds are often constructed along river margins. • Run-type reaches; low gradient and flood plain sections • Velocity: 2–99 cm/s • Turbidity: 0.1–1.0 NTU • Oxygen: Intergravel 8–12 mg/L, mean 9 mg/L; Instream 10–11.5 mg/L, mean 10 mg/L • Water Temperature: Spawning 5–9 °C; Incubation 1.2–5.4 °C; perennial groundwater upwellings are important in maintaining temperature • Fluvial and adfluvial Bull Trout migrate to spawning habitat, thus unobstructed access is required	• Unimpeded access to spawning areas • Gravel/cobble dominated substrate associated with perennial groundwater upwellings *Areas with minimal disturbances and low levels of fine sediment*

Life Stage	Function	Feature(s)	Attributes (Observed)	For Identification of Critical Habitat (Inferred)
Young-of-Year	Nursery Cover Feeding *Overwintering*	• Shallow shoreline pools and riffles of side channels; deeper pools; interstices of bottom substrate; often overwinter in areas associated with perennial groundwater upwellings	• Depth range: 0.07–0.93 m • Substrate: cobble and boulder, silt • Cover: overhanging vegetation, undercut banks, large woody debris, gravel substrate, boulders, small wood, cobble, velocity breaks (29) • Velocity: low velocity backwaters and side channels • Nose velocity: 0–0.1 m/s; upper limit: 0.33 m/s • Bottom velocity: 0.05–0.15 m/s; upper limit: 0.23 m/s • Water Temperature: 2–20 °C; ultimate upper incipient lethal temperature (UUILT) 20.9 °C (60 days), 23.5 °C (7 days) • Pool and run habitats are preferred • Connectivity between spawning sites and rearing locations	• Low velocity backwaters and side channels; pool and run habitats • Adequate cover (intact riparian zone) • Seasonal and perennial groundwater upwellings • Connectivity between spawning sites and rearing locations
Juvenile and Adult	Feeding Cover Overwintering	• Higher gradient habitats, often in shallow pools and riffles; interstices of bottom substrates; often overwinter in isolated pools maintained by perennial groundwater upwellings • Pools, riffles, runs, lakes (adfluvial)	• Gradient: 1.0–15.6% • Depth: deeper water during the day and shallower water (littoral zone, runs, channel margins, backwaters) at night; pools associated with groundwater input for overwintering • Substrate: cobble, boulder, silt (juveniles), rubble, sand (night use) • Cover: overhanging vegetation, undercut banks, large woody debris, substrate, boulders, rootwads (juveniles), velocity breaks (juveniles), may also use deep-water habitat; diel shifts to habitats without cover at night are common • Oxygen: acute limit = > 2 mg/L; likely the same for juveniles and adults • Water Temperature: below 12 °C; UUILT slightly lower than for young-of- year; maximum daily-maximum temperature 12 °C, maximum weekly-maximum temperature 11 °C; average maximum summer temperature 17 °C • Fluvial Bull Trout migrate to overwintering areas and therefore require well-connected habitat • Velocity (Juvenile) – Nose velocity: 0.05–0.25 m/s, upper limit: 0.48 m/s; Bottom velocity: 0.20–0.28 m/s, upper limit: 0.31 m/s, Mean column velocity: 0.0–0.20 m/s, upper limit: 0.8 m/s	• Unimpeded access to overwintering areas • Adequate cover (intact riparian zone) • Pools and riffles • Seasonal and perennial groundwater upwellings

Limiting Factors

The most significant natural limiting factor for Bull Trout is its habitat specificity, particularly water temperature (typically less than 12 °C) and spawning and rearing habitat requirements that strongly influence its distribution. Density-dependent survival, its position as a top aquatic predator and its high site fidelity can contribute to relatively low densities. These factors, along with its restricted gene flow and naturally fragmented distribution, make Bull Trout vulnerable to local extinctions through stochastic processes. These naturally occurring limiting factors make Bull Trout vulnerable to anthropogenic disturbances.

Bull Trout however have evolved strategies to persist in variable environments with phenotypic plasticity and density-dependent changes in life history traits (e.g., faster maturation and increased frequency of reproduction at lower densities). These strategies may provide some degree of compensation for human-induced changes.

Threats

A wide variety of threats negatively impact Bull Trout across its range. The greatest threats to the survival and persistence of Bull Trout in DU 4 are related to habitat fragmentation, habitat removal and alteration, mortality (e.g., fishing-related mortality), and interaction with introduced species (e.g., competition, hybridization). Climate change, and interactive and cumulative effects are also important threats to Bull Trout. Sawatzky (2016) provides a detailed description of the principal threats to Bull Trout in DU 4. Note that only existing and imminent threats are considered. Potential future threats (e.g., new invasive species, such as Zebra Mussel, and diseases[1]) were not considered.

Habitat Fragmentation

Connectivity (i.e., unobstructed passage through watersheds) is a key habitat requirement for migratory Bull Trout. It is important in linking spawning, rearing and overwintering habitats and in linking populations to facilitate gene flow and aid in the re-establishment of declining populations.

Habitat fragmentation is caused by the creation of migratory barriers including elevated or undersized culverts, dams without fish passage facilities, water diversion canals or water withdrawal practices that entrain fish or decrease stream flow, and land-use practices that negatively impact habitat making it uninhabitable for Bull Trout. Large dams built between 1911 and 1991 were designed without fish passage facilities. Low head dams (weirs) generally have fish ladders although these often require regular maintenance and/or upgrading. Irrigation canals fragment habitat by decreasing instream flows which can cause increases in water temperature above Bull Trout tolerance limits and by entraining migrating Bull Trout that move into the canals below water control structures within the canal system.

The impacts of fragmentation on Bull Trout vary, but typically result in range contractions and population declines and may delay or preclude fish assemblage recovery following a disturbance. Fragmentation may also result in rates of extinction or extirpation exceeding rates of habitat loss by decreasing the chance of recolonization through regional connectivity. Benefits if habitat fragmentation were abated would be to allow recolonization in the event of

[1] In September 2016, it was reported that the presence of whirling disease has been confirmed in the upper Bow River, downstream of the confluence of the Bow and Cascade rivers within Banff National Park. The disease, which affects salmonids, was first identified in late August in Johnson Lake in Banff National Park. This was the first discovery of this disease, in Canada. This discovery occurred after the RPA meetings and was unexpected; it was not considered during the RPA process.

local extirpations. However, this may also allow other competing species access to habitats thereby resulting in increased competition.

The extent of spatial configuration constraints in areas occupied by Bull Trout in DU 4 has not been quantified. However, it is likely that potential pathways of genetic interchange have been lost through the reduction in connectivity or the construction of barriers. The current locations of instream barriers are identified in Figure 2 with more details on the location and specifications for dams in Sawatzky (2016).

Figure 2. Location of natural waterfalls and man-made dams that may act as barriers to fish passage in DU 4.

Habitat Removal and Alteration

Various activities such as residential and industrial development, mining, grazing, agriculture, forestry, irrigation, dams, road construction and recreational development can damage or destroy habitat properties by altering natural flow regimes, increasing sediment input and/or altering stream thermal regimes. These activities may also lead to contaminant and toxic substance inputs, and nutrient loading. Sawatzky (2016) describes the impacts on Bull Trout.

The activities that may have directly or indirectly affected Bull Trout habitat include watercourse crossings (e.g., bridges, culverts, open cut crossings), shoreline/streambank work (e.g., stabilization, infilling, retaining walls, riparian vegetation management), mineral aggregate, oil and gas exploration, extraction and/or production, instream works (e.g., channel maintenance, restoration, modifications, realignments, dredging, aquatic vegetation removal), water management (e.g., stormwater management, water withdrawal), structures in water (e.g., boat launches, docks, effluent outfalls, water intakes) and other projects (e.g., conduit installation on bridge, bridge washing).

DFO's Fisheries Protection Program database (Program Activity Tracking for Habitat; PATH) includes information on works, activities and projects reported to DFO. Table 4 summarises the 673 projects undertaken in DU 4 known to be occupied by Bull Trout from January 2008–March 2014 and reported to DFO. In addition to those projects that could affect Bull Trout habitat, PATH also includes activities dealing with control of nuisance species, contaminated site remediation and habitat improvement (e.g., habitat restoration).

Mortality

Mortality, injury or reduced survival resulting principally from fishing activities (e.g., angling mortality, recreational by-catch, poaching, scientific sampling) and from entrainment at hydroelectric facilities and in irrigation canals impact Bull Trout. Lethal effects on Bull Trout can result from the release of contaminants and toxic substances.

Life history and behavioural characteristics of Bull Trout make them more vulnerable than other species. They are slow growing, late to mature and their opportunistic and aggressive feeding behaviour increase their vulnerability to angling, especially when bait is used. They also form spawning aggregations in clear shallow water, making them easy targets for anglers. Angler access has increased substantially over the past 50 years with industrial development (forestry, mining, fossil fuels). A province-wide zero harvest regulation was implemented in Alberta in 1995, but prior to this Bull Trout were overexploited throughout the province in accessible areas. Even with the zero harvest regulation, poaching and misidentification are still a problem.

Campaigns to educate anglers began in the 1990s and have had some success. Catch and release fisheries may also be a source of mortality from hooking-caused injuries. In the Belly and Waterton rivers, hooking mortality was estimated to be 5%. In systems where introduced sport fish are present, by-catch of Bull Trout by anglers targeting other trout species is also a concern. Simulations using reasonable estimates of fishing effort and associated mortality showed that restrictive angling regulations will continue to be required for many Bull Trout populations if they are to be sustained.

Scientific sampling is a low risk threat, but is a potential source of mortality. This activity is controlled by permitting and sampling protocols are followed.

Introduced Species

Introductions of competitive species including Lake Trout, Brook Trout and Brown Trout have contributed to Bull Trout declines, range contraction and extirpations within Alberta. Temperature requirements, relatively slow growth, late maturity and variable spawning frequency make Bull Trout particularly susceptible to competition with introduced species. In many cases they have been out-competed resulting in reduced abundance and population viability. Lake Trout are the most frequently implicated species in the competitive displacement or replacement of Bull Trout in lakes and Brook Trout are more frequently implicated in streams. Brown Trout are likely replacing, rather than displacing, Bull Trout as Bull Trout declines have been observed to precede increases in Brown Trout. However, this requires further research.

The impacts of Brook Trout invasion into Bull Trout streams range from no impact to complete replacement of Bull Trout. Bull Trout may be displaced into smaller and more isolated populations in headwater streams. These populations are at increased risk to local extinction through other causes.

Table 4. Summary of the number of works, projects and activities that have occurred during the period from January 2008 to March 2014, as determined from the project assessment analysis, in areas known to be occupied by Bull Trout (DU 4) by watershed. Threats known to be associated with these types of works, projects, and activities have been indicated by a checkmark. Applicable Pathways of Effects have been indicated for each threat associated with a work, project or activity (1–Vegetation clearing; 2–Grading; 3–Excavation; 4–Use of explosives; 5–Use of industrial equipment; 6–Cleaning or maintenance of bridges or other structures; 7–Riparian planting; 8–Streamside livestock grazing; 9–Marine seismic surveys; 10–Placement of material or structures in water; 11–Dredging; 12–Water extraction; 13–Organic debris management; 14–Wastewater management; 15–Addition or removal of aquatic vegetation; 16–Change in timing, duration and frequency of flow; 17–Fish passage issues; 1 –Structure removal; 19–Placement of marine finfish aquaculture site).

Work/Project/Activity	Threats							Watershed			
	Alteration of Natrual Flow Regimes	Suspended and Deposited Sediments	Alteration of Stream Temperature	Alteration of Groundwater Quality or Quantity	Invasive species	Contaminants and Toxic Substances	Nutrient Loading	Oldman	Bow	Red Deer	North SK
Applicable pathways of effects for threat mitigation and project alternatives	16	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 18	1, 3, 7, 8, 14, 15, 16, 17	3	14, 17	1, 4, 5, 6, 7, 11, 13, 14, 15, 16, 18	1, 4, 7, 8, 10, 11, 13, 14, 15, 16				
Watercourse crossings (e.g., bridges, culverts, open cut crossings)	✓	✓				✓	✓	54	103	53	63
Shoreline, streambank work (e.g., stabilization, infilling, retaining walls, riparian vegetation management)	✓	✓	✓			✓	✓	38	67	26	10
Mineral Aggregate, Oil & Gas Exploration, Extraction, Production	✓	✓		✓		✓		1	4	2	7
Instream works (e.g., channel maintenance, restoration, modifications, realignments, dredging, aquatic vegetation removal)	✓	✓				✓	✓	28	45	14	15

Work/Project/Activity	Threats							Watershed			
	Alteration of Natrual Flow Regimes	Suspended and Deposited Sediments	Alteration of Stream Temperature	Alteration of Groundwater Quality or Quantity	Invasive species	Contaminants and Toxic Substances	Nutrient Loading	Oldman	Bow	Red Deer	North SK
Applicable pathways of effects for threat mitigation and project alternatives	16	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 18	1, 3, 7, 8, 14, 15, 16, 17	3	14, 17	1, 4, 5, 6, 7, 11, 13, 14, 15, 16, 18	1, 4, 7, 8, 10, 11, 13, 14, 15, 16				
Water management (e.g., stormwater management, water withdrawal)	✓	✓				✓	✓	9	33	7	16
Structures in water (e.g., boat launches, docks, effluent outfalls, water intakes)	✓	✓	✓					12	15	3	4
Control of Nuisance Species								1			
Contaminated Site Remediation										1	
Habitat Improvement (e.g., habitat restoration)								2	6	5	
Other (e.g., conduit installation on bridge, bridge washing)								3	13	3	10
Invasive species introductions (authorized and unauthorized)					✓						
TOTAL								148	286	114	125

It is likely that competitive displacement by Brook Trout is a greater threat to resident Bull Trout than to the migratory form. Residents have an increased direct niche overlap with Brook Trout (e.g., similar diet, occur in small headwater streams) for their entire life cycle, whereas migratory Bull Trout move downstream to higher stream orders and shift to piscivory at the end of their juvenile phase.

In addition to competitive replacement or displacement, hybridization with Brook Trout may also be a threat to Bull Trout. Hybridization between Bull Trout and Brook Trout has been confirmed in Alberta, but the extent of impacts is unknown.

Climate Change

In the Rocky Mountains, climate warming is occurring at two to three times the rate of the global average. In parts of Alberta, the mean temperatures of the warmest month have increased by at least 1 °C, the frost-free period has increased by close to 20 days, and growing-degree-days (GDD) have increased by up to 200 GDD > 5 °C. This pattern is expected to continue, possibly resulting in a future reduction to the winter incubation period for fall-spawning fish. Increasing temperatures could result in significant loss of thermally suitable spawning and rearing habitat, feeding, migrating and overwintering habitat area and may also cause habitat fragmentation.

Precipitation-as-rain has been increasing in the northern mountains, parkland and northern foothills, and has been stable or declining in other areas of Alberta. Precipitation-as-snow is stable, or possibly declining, in most regions. With little to no increase in precipitation and warmer temperatures, the amount of water lost to evaporation is compounding the effects of warmer temperatures on fishes. Snowpack and glacial meltwater maintain river and groundwater supplies but the Bow, Saskatchewan and Athabasca glaciers are shrinking rapidly. Winter snowpack is expected to contribute much less meltwater and the spring melt is predicted to occur earlier in the year compounding the effects of drought. Higher latitudes and altitudes will be most impacted by these conditions as climate continues to warm.

Extreme weather events (e.g., floods, droughts) are predicted to increase as climate warms although the extent to which this will occur is uncertain. In June of 2013, a high amount of precipitation combined with saturated ground caused “unprecedented” flooding in Alberta. The flooding of the Bow River was the largest flood event since 1932 and produced a peak discharge (1,470 m^3/s) nearly 15 times that of the daily mean (106 m^3/s).

Large floods may cause bed scour strong enough to destroy Bull Trout redds, embryos and alevins prior to emergence and may displace newly emerged fry. Drought conditions may lead to an increase in wildfires which, in turn, may cause loss of riparian vegetation thereby reducing shade and causing an increase in water temperature. Large disturbances following a severe wildfire, such as extreme flooding and debris flow, may cause local extirpations. Longer term effects, such as changes in channel form and increased water temperatures, may cause changes in riverine food webs, have temperature-related physiological impacts on fish, and increase mortality or local extirpations if water temperatures increase beyond lethal limits.

Interactive and Cumulative Effects

Cumulative environmental effects result from the incremental effect of an action when added to past, present and reasonably foreseeable future actions. Large declines in Bull Trout were predicted from the combined impacts of increasing temperatures, decreasing summer flows, and increasing winter high flows. Investigations of the interactive and cumulative effects of forest harvesting, oil and gas development and road networks on the occurrence and abundance of Bull Trout in two river drainages in Alberta (DU 2) found negative impacts for the majority of sites tested. Projections predicted local extirpations of Bull Trout from up to 43% of stream reaches within 20 years with an increase in forest harvesting of up to 35% of individual watersheds.

Climate change can interact with other stressors by affecting the timing, spatial extent and/or intensity of effects of those stressors and may also limit the ability of an ecosystem to recover following a disturbance. Some stressors may also make ecosystems more vulnerable to climate change. For example, damage caused by deforestation (e.g., reduction of shade in riparian areas) can decrease the resiliency of an ecosystem to climate change and may even contribute to climate change by releasing stored carbon into the atmosphere. Deforestation may also cause local warming and reduced rainfall, exacerbating climate change impacts. Water withdrawals for agricultural purposes may increase with reduced precipitation or drought further exacerbating impacts of climate change on freshwater ecosystems.

Alberta Environment and Parks is currently working on a cumulative effects modelling approach to aid in the determination of the primary threats to watersheds.

The potential ecological impacts of threats to Bull Trout were not evaluated for co-occurring species in DU 4 and there was no evaluation of the benefits and disadvantages of threat abatement to Bull Trout or other co-occurring species.

The Alberta Conservation Association conducts much of the ongoing Bull Trout research and monitoring. No specific monitoring efforts were identified for Bull Trout and other co-occurring species associated with each of the threats nor were specific knowledge gaps identified.

Threat Assessment

Sawatzky (2016) determined threat levels at the HUC, watershed and DU level. Climate Change, and Interactive and Cumulative Effects were only assessed at the DU level. The highest level of risk for a given HUC was retained for each watershed and the highest level in the watersheds were retained for the DU. As a result, all threats were considered High risk to Bull Trout at the DU level. Table 5 summarizes the threat levels for each of the DU 4 watersheds. HUC level threats assessment is included in Sawatzky (2016).

Mitigation and Alternatives

Threats to survival can be minimized by implementing mitigation measures to reduce or eliminate potential harmful effects that could result from works or undertakings associated with projects or activities in Bull Trout habitat. DFO has developed guidance on mitigation measures for 19 Pathways of Effects for the protection of aquatic species at risk in the Central and Arctic Region (Coker et al. 2010). This guidance should be referred to when considering mitigation and alternative strategies for habitat-related threats. Table 4 summarizes applicable pathways of effects associated with each activity reported to DFO that have occurred from January 2008–March 2014 in Bull Trout (DU 4) watersheds.

To minimize interactions with introduced species, the following mitigations may be appropriate:

- Physically remove non-native species from areas known to be inhabited by Bull Trout.
- Monitor range of Bull Trout, DU 4 for exotic/invasive species that may negatively impact Bull Trout directly, or affect Bull Trout preferred habitat.
- Develop a plan to address potential risks, impacts and proposed actions if monitoring detects the arrival or establishment of exotic/invasive species.
- Introduce a public awareness campaign and encourage the use of existing exotic species reporting systems.

Table 5. Watershed-level Threat Level, Threat Occurrence, Threat Frequency and Threat Extent. The highest level of risk for a given HUC was retained. Interactive and Cumulative Effects, and Climate Change were only assessed at the DU level.

THREAT	Threat Level	Threat Occurrence	Threat Frequency	Threat Extent	Threat Level	Threat Occurrence	Threat Frequency	Threat Extent
	Oldman				Bow			
Competition and Hybridization with Brook Trout	Low	Current	Continuous	Broad	Medium	Current	Continuous	Broad
Competition with Lake Trout	Medium	Current	Continuous	Broad	High	Current	Continuous	Broad
Mortality (e.g., angling, scientific sampling)	High	Historical, Current	Recurrent	Broad	High	Historical, Current	Recurrent	Broad
Habitat Fragmentation								
Culverts (Road Density Proxy)	High	Current	Continuous	Broad	High	Current	Continuous	Broad
Dams and Weirs	High	Historical, Current	Continuous	Extensive	High	Historical, Current	Continuous	Extensive
Irrigation Canals	Medium	Current	Continuous	Narrow	Medium	Current	Continuous	Narrow
Habitat Alteration								
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	High	Current	Recurrent	Broad	High	Current	Recurrent	Broad
Suspended and Deposited Sediments	High	Current	Recurrent	Broad	High	Current	Recurrent	Broad
Alteration of Stream Temperature (change from natural)	High	Current	Continuous	Broad	Medium	Current	Continuous	Broad
Alteration of Groundwater Quantity or Quality	High	Current, Anticipatory	Single, Recurrent	Extensive	High	Current	Single, Recurrent	Extensive
Nutrient Loading	High	Current, Anticipatory	Recurrent	Broad	High	Current, Anticipatory	Recurrent	Broad
Contaminants and Toxic Substances	High	Current, Anticipatory	Single, Recurrent	Broad	High	Current, Anticipatory	Single, Recurrent	Broad

THREAT	Threat Level	Threat Occurrence	Threat Frequency	Threat Extent	Threat Level	Threat Occurrence	Threat Frequency	Threat Extent
	Red Deer				North Saskatchewan			
Competition and Hybridization with Brook Trout	High	Current	Continuous	Broad	Low	Current	Continuous	Broad
Competition with Lake Trout	Low	Current	Continuous	Broad	Low	Current	Continuous	Broad
Mortality (e.g., angling, scientific sampling)	High	Historical, Current	Recurrent	Broad	High	Historical, Current	Recurrent	Broad
Habitat Fragmentation								
Culverts	High	Current	Continuous	Broad	High	Current	Continuous	Broad
Dams and Weirs	Low	Historical, Current	Continuous	Extensive	High	Historical, Current	Continuous	Extensive
Irrigation Canals	Medium	Current	Continuous	Narrow	High	Current	Continuous	Narrow
Habitat Alteration								
Alteration of Natural Flow Regimes (disruption of peak flow intensity, roads, dams)	High	Current	Recurrent	Broad	High	Current	Recurrent	Broad
Suspended and Deposited Sediments	Medium	Current	Recurrent	Broad	Medium	Current	Recurrent	Broad
Alteration of Stream Temperature (change from natural)	Medium	Current	Continuous	Broad	HIgh	Current	Continuous	Broad
Alteration of Groundwater Quantity or Quality	High	Current	Single, Recurrent	Extensive	High	Current	Single, Recurrent	Extensive
Nutrient Loading	High	Current, Anticipatory	Single, Recurrent	Broad	High	Current, Anticipatory	Single, Recurrent	Broad
Contaminants and Toxic Substances	Medium	Current, Anticipatory	Single, Recurrent	Broad	High	Current, Anticipatory	Single, Recurrent	Broad

There are no alternatives to unauthorized introduction. Authorized introductions should follow the National Code on Introductions and Transfers of Aquatic Organisms.

To minimize impacts of fishing-related mortality, the following mitigations may be appropriate:

- Fishery closures
- Catch and release only (province-wide zero-bag limit has been in effect since 1995)
- Public Education to reduce misidentification and increase awareness of regulations
- Barbless hooks to reduce hooking mortality
- Using non-lethal sampling methods for scientific sampling

Consideration should be given to allowable-harm recommendations when collection for scientific purposes is necessary.

Strategies to mitigate the negative impacts of climate change are becoming increasingly important. For migratory fishes, such as Bull Trout, conserving the connectivity, size and extent of high quality habitats and helping to guide habitat restoration efforts are important strategies to mitigate the effects of climate change. Areas with the coldest water temperatures have the best long-term potential to support the species, and genetic diversity in populations may offer resilience to climate warming.

The mitigation measures outlined are consistent with the goal of increasing survivorship, by reducing threats to the species directly or indirectly by improving habitat quality.

Population Sensitivity

When considered cumulatively by life stage, Bull Trout population growth was most sensitive to changes in the survival of juveniles for each population type.

Productivity and survivorship parameters can be increased if the listed threats to the different life-history stages are reduced. For example, reducing fishing mortality will increase juvenile/adult survival.

For populations with a declining population ($\lambda < 1$) the amount of change to a vital rate required to increase the population growth rate to 1 (stable) can be calculated. An increase in the juvenile or adult survival rates (σ_J or σ_A), or a decrease in the spawning periodicity (T) of 24%, 79%, 74%, respectively, for the small growth trajectory fish and 25%, 85%, 74%, respectively, for the large trajectory fish could increase a λ of 0.9 to 1. No amount of increase to any individual vital rate could increase a λ of 0.75 or lower to 1 for any population type. It is important, however, to consider that there may be biological limits to increasing vital rates. Recovery efforts that increase vital rates for more than one life stage should be considered preferential over those that only target one life stage.

Recovery Targets

Abundance Targets (MVP)

Demographic sustainability was used as a criterion to identify recovery targets for Bull Trout. Demographic sustainability is related to the concept of a minimum viable population (MVP) and was defined as the minimum adult population size that results in a desired probability of persistence over 100 years (approximately 12 generations for Bull Trout). MVP targets were chosen to optimize the benefit of reduced extinction risk and the cost of increased recovery effort. To achieve demographic sustainability (i.e., a self-sustaining population over the long term), under conditions with a 15% chance of catastrophic mortality event per generation and a quasi-extinction threshold of 50 adults, the adult Bull Trout abundance needs to be at least 1.9 million adult Bull Trout. Targets for alternative risk scenarios ranged from about 95 adults to about 30 million adults and are highly sensitive to the extinction threshold, the probability of catastrophic mortality, and the ratio of individuals from small and large-bodied growth trajectories in the population (Figure 3).

There are insufficient data to provide meaningful population trajectories for the species in DU 4. Data on current population sizes and trends are uncertain and within DU 4, Bull Trout exhibit three life history types (i.e., resident, fluvial, or adfluvial) with different population trajectories that can vary by waterbody. The current amount of mixing of life-histories for the Saskatchewan-Nelson River populations is unknown.

A total of 45 Bull Trout HUCs were delineated within DU 4, seven with stable trajectories, 31 with decreasing trajectories and the remaining seven considered extirpated. Of the current sub-populations, 28% contained only residents, 23% had only fluvial or adfluvial populations and 47% were mixed. The estimated size of all the populations in DU 4 combined is between 6,359 and 21,700 total mature individuals, with the individual population estimates in the core areas ranging from 10 to 1,275 mature individuals.

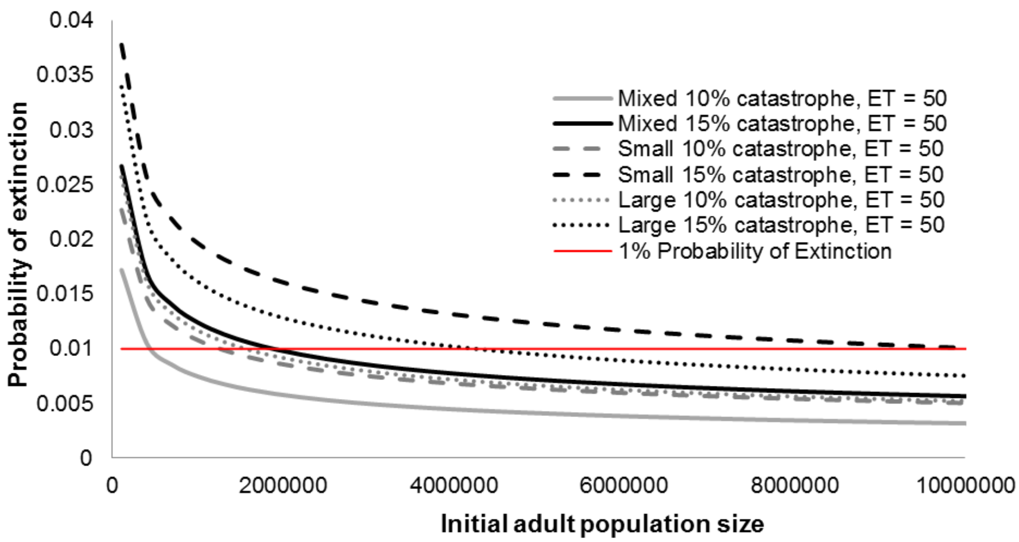

Figure 3. Probability of extinction, at the quasi-extinction thresholds (ET) of 50 adults, within 100 years of 10 simulated Bull Trout populations, at equilibrium, as a function of adult population size. Curves represent different combinations of population type and probability of catastrophe per generation (%). Red horizontal reference line is at 0.01 and intersects curves at the associated MVPs.

At the current estimate of abundance, using the most conservative estimate of MVP (extinction threshold of 50 individuals with a 15% generational risk of catastrophe) the minimum number of years it would take to achieve the MVP was estimated for populations growing at λ_{max} (Table 6). However, the actual population growth rate will most likely be lower than λ_{max}, and will slow down as the population size increases due to density dependence.

For large, mixed, and small population types the average waterbody, at a probability of extinction of 0.01, will take approximately 39, 28, or 19 years, respectively, to obtain the MVP. For large, mixed, and small population types the average basin, at a probability of extinction of 0.01, will take approximately 29, 20, or 15 years, respectively, to obtain the MVP. For large, mixed, and small population types the total population, at a probability of extinction of 0.01, will take approximately 23, 16, or 12 years, respectively to obtain the MVP.

Table 6. Number of years required to achieve the minimum viable population (MVP) size (adults) for large, mixed and small growth trajectory population types, with an extinction threshold of 50 individuals, five different probabilities of extinction (P_{ext}), and a probability of generational catastrophe (GC) of 15% for each of the Oldman River, Bow River, Red Deer River and North Saskatchewan River basins in DU 4.

Waterbody	Current Abundance Estimate	Large					Mixed					Small				
		0.001	0.01	0.03	0.05	0.08	0.001	0.01	0.03	0.05	0.08	0.001	0.01	0.03	0.05	0.08
Oldman River Basin	1940	55.9	29.3	16.6	10.7	5.3	40.6	20.4	10.8	6.4	2.3	28.1	14.6	8.1	5.1	2.4
Bow River Basin	2623	54.8	28.2	15.5	9.6	4.2	39.7	19.5	9.9	5.5	1.4	27.6	14.1	7.6	4.6	1.9
Red Deer River Basin	540	60.8	34.2	21.5	15.6	10.2	44.4	24.2	14.6	10.2	6.1	30.3	16.8	10.3	7.3	4.6
North Saskatchewan River Basin	5115	52.2	25.6	12.9	7.0	1.6	37.7	17.6	8.0	3.5	0.0	26.4	12.9	6.5	3.5	0.7

Habitat Targets (MAPV)

Minimum area for population viability (MAPV) is a quantification of the amount of habitat required to support a viable population with the desired probability of persistence. Variables included in the MAPV assessment include MVP values and area required per individual (API values). API values were estimated from an allometry for river environments from freshwater fishes. MAPV for the population achieving demographic sustainability would be 510 km^2 of suitable Bull Trout habitat. MAPV for alternative risk scenarios ranged from about 14,000 m^2 to about 4,300 km^2 of suitable habitat.

Occupancy estimates for the DU 4 Bull Trout in several waterbodies are summarized in the Appendix (Table A1). The estimated historical distribution of Bull Trout in this DU was 24,000 km of stream habitat, which has reduced over the years and is currently estimated at approximately 16,000 km. Assuming an average stream width of 10 m, the total available habitat for Bull Trout is between 160 km^2 and 240 km^2, so does not meet the requirements for the most conservative MVP estimates. With the current available habitat falling short of the MAPV targets, it is possible that the most conservative MVP may be unattainable. Furthermore, this MAPV estimate assumes that the entire area is suitable habitat. If certain areas of the current available habitat are deemed partially unsuitable, the total minimum required area should be increased.

The feasibility of rehabilitating or restoring degraded habitat features such as the riparian zone, and headwaters, has not been assessed. A more complete estimate of available and suitable habitat is needed including information on the amount of habitat present that could be restored. Restoration may not be feasible in some watersheds due to the extent and nature of changes in the watershed. Further research is needed to identify and prioritize the streams in highest need of restoration in areas where Bull Trout abundance/range has been reduced.

Allowable Harm

Allowable harm is defined as harm to the population that will not jeopardize population recovery or survival. Chronic harm refers to a negative alteration to a vital rate (survival, fecundity, etc.) that reduces the annual population growth rate permanently or over the long term. Transient harm refers to a one-time removal of individuals such that survival (and therefore population growth rate) is only affected in the year of the removal.

To avoid jeopardizing the survival and future recovery of Bull Trout, human-induced harm to the annual survival of juveniles should be minimal. Elasticities for fecundity were greater for populations with the large growth trajectory than for those with the small growth trajectory.

Analyses of chronic harm show that if the Bull Trout population is growing at maximum population growth (λ_{max}), a removal of 46% of the juveniles for populations with the small growth trajectory, will bring population growth down to $\lambda = 1$. At maximum population growth, if all other vital rates are held constant, the population growth rate will not be reduced to 1 by changes in individual vital rates for the other stages in the small growth trajectory populations and mixed growth trajectory populations.

Transient harm may be applied without jeopardizing survival or recovery if the population is not in decline. For small and mixed bodied population types, removal of ~10% and for the large bodied population type removal of ~15%, of the total population will result in a 1% decline in population growth rate for a stable population. Removal of 25% of all individuals for the mixed 30% for the large, and 35% for the small bodied population type of every 10 years will reduce the growth rate to 1 if the population is growing at λ_{max} (i.e., this removal will result in a stable population). Absolute numbers for removal should be chosen based on the population abundance. Allowable transient harm may be smaller if the population is growing at a slower rate. We caution that any removal affects population growth rate and will delay recovery, and that current population abundance estimates are very uncertain.

Sources of Uncertainty

Some elements of the life history of Bull Trout are unknown. While individual growth and fecundity of Bull Trout has been well studied and seems consistent over time, estimates of annual mortality are highly variable for all age classes.

Some life-history parameters for Bull Trout have been shown to be density dependent (i.e., spawning periodicity, survival and growth rates). There was not enough information, however, to include density-dependence in the modelling, and may result in changes in the estimates of probability of extinction. Further, MVP estimates differed dramatically based on the assumed population growth trajectory type (mixed, large growth trajectory, or small growth trajectory), frequency of catastrophic decline, and extinction threshold. If recovery targets are set based on an incorrect population type or rate of catastrophes, then risk of extirpation may be greater. Further research in this area is warranted.

Current population connectivity and abundance estimates for Bull Trout are very uncertain. Incorrect assumptions regarding abundance will affect estimates of population trajectory, and may result in profound changes in allowable harm advice. Uncertainty in population abundance should be reduced.

Predictions from modelling assume random mating and complete mixing of the population (i.e., all individuals interact and can reproduce with one another). One of the main potential threats to the Bull Trout population is habitat fragmentation, implying incomplete mixing. This assumption should be considered when applying MVP to the setting of recovery targets, and larger total targets should be set if the assumption does not hold.

Estimates of required habitat (MAPV) assume that habitat is of high quality throughout the range of Bull Trout. There in sufficient data to either confirm, or provide an alternative to this assumption. However, one of the main potential threats to the Bull Trout population is habitat degradation; the extent Bull Trout habitat is declining due to climate change and anthropogenic pollution (COSEWIC 2012). Further study is needed to assess the extent of suitable habitat for Bull Trout.

Numerous threats have been identified for Bull Trout in DU 4. There is a need for more causative studies to evaluate the impact of each threat on Bull Trout with greater certainty as well as an estimation of the cumulative effects of interactive threats. Examples include:

- mechanisms allowing Bull Trout to resist invasion and the interactions of these mechanisms with habitat disturbance;
- effects of anthropogenic stressors on groundwater (cause-effect linkages);
- investigating the successful fertility rate of a spawning events between Bull Trout and Brook Trout, as there could be an increase in wasted reproduction effort if the offspring are not viable; and,
- the impact of fishing pressure (recreational by-catch – hooking or illegal and handling stress, delayed mortality) on Bull Trout energetics and growth and reproductive success.

There is also a need to improve our understanding of the physiological capacity of populations as they relate to environmental regimes (e.g., stream temperatures, flow/discharge). These types of studies examine the physiological limitations of populations and their capacity to adapt and evolve as environmental regimes are altered. They provide a mechanistic understanding of how stressors may affect individuals and populations. For Bull Trout, increasing water temperatures and changes to annual stream temperature regimes will likely be the most relevant for recovery. Flow regimes are closely tied to this and will continue to be a concern in Alberta. Parallel genomic work to determine if populations have adapted to local environmental conditions should be conducted. The effects of potential mitigation measures, for example, the impact of non-native species removal on the persistence of Bull Trout populations, should also be investigated. Threats were assessed at the HUC8 level and rolled up to the watershed and DU levels. However, the degree of Bull Trout movement between HUCs is largely unknown and was therefore not accounted for.

SOURCES OF INFORMATION

This Science Advisory Report is from the June 15, 2016 Recovery Potential Assessment of Bull Trout, *Salvelinus confluentus* (Saskatchewan – Nelson rivers populations). Additional publications from this meeting will be posted on the DFOScience Advisory Schedule as they become available.

Caskenette, A.L. Young, J.A., and Koops M.A. 2016. Recovery potential modelling of Bull Trout (*Salvelinus confluentus*) (Saskatchewan–Nelson rivers populations) in Alberta. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/099. iv + 40 p.

Coker, G.A., Ming, D.L., and Mandrak, N.E. 2010. Mitigation guide for the protection of fishes and fish habitat to accompany the species at risk recovery potential assessments conducted by Fisheries and Oceans Canada (DFO) in Central and Arctic Region. Version 1.0. Can. Manuscr. Rep. Fish. Aquat. Sci. 2904: vi + 40 p.

COSEWIC. 2012. COSEWIC assessment and status report on the Bull Trout *Salvelinus confluentus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. iv + 103 p.

DFO. 2017. Proceedings of the regional recovery potential assessment (RPA) of Bull Trout, *Salvelinus confluentus,* (Saskatchewan–Nelson rivers populations); June 4–5, 2014 and June 15, 2016. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2016/046.

Sawatzky, C.D. 2016. Information in support of a recovery potential assessment of Bull Trout (*Salvelinus confluentus*) (Saskatchewan–Nelson rivers populations) in Alberta. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/113. v + 190 p.

Stewart, D.B., Mochnacz, N.J., Sawatzky, C.D., Carmichael, T.J., and Reist, J.D. 2007. Fish diets and food webs in the Northwest Territories: Bull Trout (*Salvelinus confluentus*). Can. Manuscr. Rep. Fish. Aquat. Sci. 2800: vi + 18 p.

APPENDIX

Table A1. Abundance and occupancy estimates for the Saskatchewan-Nelson rivers (DU 4) populations of Bull Trout in Alberta. The assessment was completed by the Fish and Wildlife Division of Alberta Sustainable Resource Development. Estimated adult population abundance (using quantitative data and/or expert opinion) are accompanied by appropriate NatureServe Range Categories in parentheses. Core areas currently occupied by Bull Trout were the focus, thus this is not a comprehensive list of extirpated core areas. See Sawatzky (2016) for the full list of citations.

Oldman River Basin

Waterbody	HUC 8	Life History Types	Estimated Abundance (Adults)	Occupancy (stream km)
Belly River	04010302	Fluvial Resident	250 (250–1,000)	4–40
St. Mary River	04010401	Fluvial Resident	550 (250–1,000)	40–200
Upper Crowsnest River	04010102	–	–	–
Castle River and Oldman Reservoir	04010102, 04010103	Fluvial Adfluvial Resident	310 (250–1,000)	200–1,000
Upper Oldman River	04010101	Fluvial Resident	410 (250–1,000)	40–200
Upper Livingstone River	04010101	Resident	280 (250–1,000)	4–40
Lower Oldman River	04010105	Fluvial Resident	60 (50–250)	40–200
Waterton River	04010301	Resident	40 (1–50)	4–40
Drywood Creek	04010301	Resident	40 (1–50)	4–40
Willow Creek	04010201	–	–	–

Bow River Basin

Waterbody	HUC 8	Life History Types	Estimated Abundance (Adults)	Occupancy (stream km)
Lower Bow River	04020801	–	–	–
Highwood River	04021201	Fluvial Resident	190 (50–250)	40–200
Flat Creek	04020601	Resident	40 (1–50)	4–40
Sheep River	04021202	Fluvial Resident	445 (250–1,000)	40–200
Lower Elbow River	04021001	Fluvial Resident	105 (50–250)	40–200
Canyon Creek	04021001	Resident	20 (1–50)	4–40
Upper Elbow River	04021001	Resident	115 (50–250)	40–200
Jumpingpound Creek	04020802	Resident Fluvial	15 (1–50)	4–40
Ghost River	04020701	Resident Fluvial	385 (250–1,000)	40–200

Waterbody	HUC 8	Life History Types	Estimated Abundance (Adults)	Occupancy (stream km)
Middle Bow River	04020301, 04020501	Incidental	10 (1–50)	< 4
Middle Kananaskis River	04020601	Resident	Unknown	4–40
Upper Kananaskis River (Kananaskis Lakes)	04020601	Adfluvial	1200 (1,000–2,500)	40–200
Upper Spray River	04020301	Resident	40 (1–50)	4–40
Lake Minnewanka	04020501	Resident	58 (50–250)	4–40
Upper Bow River	04020101, 04020201	Resident Fluvial?	Unknown	Unknown

Red Deer River Basin

Waterbody	HUC 8	Life History Types	Estimated Abundance (Adults)	Occupancy (stream km)
Red Deer River	08010101, 08010102, 08010104, 08010201, 08010202	Fluvial Resident	530 (250–1,000)	200–1,000
Little Red Deer River	08010203	Resident	10 (1–50)	4–40

North Saskatchewan River Basin

Waterbody	HUC 8	Life History Types	Estimated Abundance (Adults)	Occupancy (stream km)
Brazeau River	11010401, 11010402, 11010404, 11010405	Fluvial Resident	1275 (1,000–2,500)	200–1,000
Blackstone River	11010403	Fluvial Resident	720 (250–1,000)	200–1,000
Nordegg River	11010401, 11010406	Fluvial	105 (50–250)	40–200
Baptiste River	11010203	Resident	50 (1–50)	40–200
Upper North Saskatchewan River	11010101, 11010102, 11010201	Fluvial	950 (250–1,000)	40–200
Pinto Lake and Cline River	11010103	Adfluvial Fluvial	1,150 (1,000–2,500)	40–200
Middle North Saskatchewan River	11010201, 11010202	Fluvial	400 (250–1000)	40–200
Lower North Saskatchewan River	11020101	Fluvial	75 (50–250)	40–200
Clearwater River	11010301, 11010302	Fluvial Resident	390 (250–1000)	40–200
Total			10,218 (6,359–21,700)	

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