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Recovery Potential Assessment for Fraser River Sockeye Salmon (*Oncorhynchus nerka),* Nine Designatable Units Part 2: Biology, Habitat, Threats, Mitigations and Allowable Harm - Elements 1-11, 14, 16-18, 22

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Nine Fraser River Sockeye Salmon Designatable Units (DUs) were assessed as Threatened or Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; 2017), and are currently under consideration for addition to Schedule 1 of the *Species at Risk Act* (SARA). This document is the second of two parts for the Recovery Potential Assessment (RPA) for these DUs. The first part of the RPA involved quantitative analysis of abundance data and generation of recovery targets, and estimating the probability of achieving these recovery targets under a range of modelled productivities and rates of en route mortality. This second part of the RPA provides an overview of biology and habitat requirements, an assessment of threats and factors potentially limiting recovery, an inventory of potential mitigation activities to increase survival and/or productivity, and a final discussion surrounding allowable harm. The major threats impacting these DUs were assessed in a multi-day workshop, held October 27th to 29th, 2020, with a range of subject-matter experts, and were identified to be climate change, geological events, natural systems modifications, fishing, pollution, and hatchery competition. These threats were subsequently reviewed during this peer-review process and revised according to group consensus. All nine DUs are faced with a unique and complex suite of threats and limiting factors depending on their geographic location, yet all DUs range from a High to Extreme level of threat risk. Based on the threats assessment, over the next three generations (2021-2032) it is expected that there will be a population level decline of 31-70% (High Risk) for DU10 Harrison (U/S)-L, DU16 Quesnel-S, DU21 Takla-Trembleur-S, and DU24 Widgeon-RT; a population level decline of 31-100% (High-Extreme Risk) for DU2 Bowron-ES, DU14 North Barriere-ES, DU17 Seton-L, DU22 Taseko-ES; and population level decline of 71% to 100% (Extreme Risk) for DU20 Takla-Trembleur-EStu. Alleviating the numerous and complex threats to these DUs will be difficult, especially as many of the threats are exacerbated by climate change. It will be critical to ensure that efforts are appropriately coordinated through effective governance to successfully mitigate the cumulative impacts of these diverse threats. Given the information presented in this RPA (Part 1 & 2), it is apparent that all sources of anthropogenic harm should be minimized to give these populations a chance to rebuild. It is our recommendation that the only activities allowed that cause mortality are those that are in support of the recovery, and in some cases survival of the DUs (i.e. DU20 Takla-Trembleur-EStu, DU2 Bowron-ES), and all sources of anthropogenic harm should be reduced to the maximum extent possible.

1. INTRODUCTION

Subsequent to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessing an aquatic species as *Threatened, Endangered* or *Extirpated*, Fisheries and Oceans Canada (DFO) undertakes a number of actions required to support implementation of the *Species at Risk Act* (SARA). Many of these actions require scientific information on the current status of the wildlife species, threats to its survival and recovery, and the feasibility of recovery. Formulation of this scientific advice has typically been developed through a Recovery Potential Assessment (RPA) within a designated timeframe following the COSEWIC assessment. This timing allows for consideration of peer-reviewed scientific analyses into SARA processes including recovery planning.

The advice from this RPA may be used to inform both scientific and socio-economic elements of the listing decision under SARA, develop a recovery and action plan, and to support decision-making with regards to the issuance of permits, agreements and related conditions. This document is the second of two parts for the RPA for Fraser Sockeye Salmon. The first part of the RPA covers quantitative analysis of recovery targets, probability of achieving recovery targets, and summarizes how these elements would contribute to the allowable harm assessment (DFO 2020a). This document covers elements related to habitat, threats, and mitigation, and will provide updated allowable harm statements from part one of the RPA.

1.1. SPECIES INFORMATION

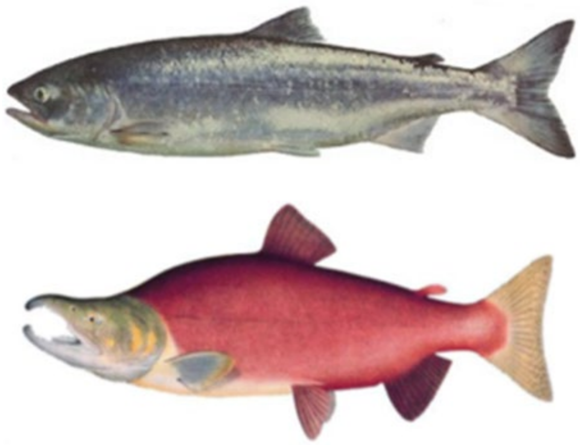

Figure 1. Sockeye Salmon adult spawning phase. Image credit: Fisheries and Oceans Canada website.

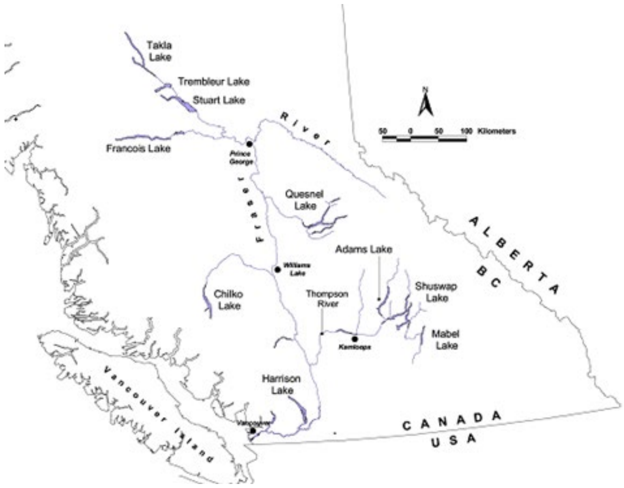

Figure 2. Map of the Fraser River watershed, British Columbia (BC), Canada.

Scientific Name: *Oncorhynchus nerka*

Common Names:

English: Sockeye Salmon, red salmon, blueback salmon (Burgner 1991); Kokanee, little redfish, silver trout (COSEWIC 2017)

French: saumon rouge (COSEWIC 2003a), saumon Sockeye (COSEWIC 2017a)

First Nations: stheqi (Halq'emeylem), Talok (Wet’suwet’en), talo (Yekooche), ts’eman (Tsilhqot’in, talook (Lhatko Dene), Talukw (Carrier Sekani) and Samman or Saumo (Michif/Chinook) (COSEWIC 2012)

Other: nerka and krasnaya ryba (Russia), benizake and benimasu (Japan); himemasu (Japan) for the non-anadromous form (Burgner 1991)

The Sockeye Salmon is one of five semelparous and anadromous Pacific salmon species native to North America, ranging from the Columbia River in the south to Kotzebue Sound in Alaska, and to the western tip of the Aleutian Islands (Augerot et al. 2005). Sockeye Salmon are an important food source for human, marine, freshwater, and terrestrial communities, and represent a cultural cornerstone providing social and ceremonial values for First Nations throughout BC (Nelitz et al. 2011; COSEWIC 2012). The Fraser River in BC historically supported the largest natural abundance of Sockeye Salmon in the world (Grant et al. 2021), and these populations have been an important contributor to a multi-million dollar commercial salmon fishery in Canada (Nelson 2006; DFO 2008).

Sockeye Salmon in the Fraser River drainage are subdivided into 24 populations, or Designatable Units (DUs), based on their geographic distribution, life history variation, timing of adult spawning migrations and genetic data (COSEWIC 2017a). There are an additional five extinct, and two potentially extirpated DUs (COSEWIC 2017a) that are not discussed in this RPA. COSEWIC DUs are derived from Wild Salmon Policy (WSP) Conservation Units (CUs) and follow the fundamental approach for maintaining genetic variability at the wildlife species level (COSEWIC 2017a); however, in some instances, multiple CUs can make up a DU. All DUs discussed in this RPA represent a single CU. Detailed descriptions of COSEWIC DUs and WSP CUs for Fraser River Sockeye Salmon can be found in Grant et al. (2011) and COSEWIC (2017a).

For the context of this RPA, all DUs spawn within the Fraser River drainage and will hereby referred to as FRS (Fraser River Sockeye). FRS DUs are genetically distinct populations that do not readily interbreed, and spawn within different geographical reaches of the Fraser River drainage (see COSEWIC 2017a for detailed description of FRS genetics and geographic distribution). Due to the variable timing of spawning returns (discussed in detail in subsequent sections), FRS are grouped into four main run timing groups: “EStu” is Early Stuart; “ES” is Early Summer; “S” is Summer; and “L” is Late; D/S is downstream, U/S is upstream and RT is River Type. These run timing groups are also used for fisheries management purposes; the DUs assessed in this RPA, and their corresponding fisheries Management Units (MUs), are summarized in Table 1.

Table 1. Fraser River Sockeye (FRS) Salmon Designatable Units (DU) and COSEWIC status (COSEWIC 2017a). Note DU names are identical to Wild Salmon Policy CU names.

Management Unit (MU)	Designatable Unit (DU) & Stock Alias	COSEWIC Status	Reason for Assessment
Early Stuart	DU20 Takla-Trembleur-EStu (Early Stuart)	Endangered	The number of mature individuals returning to DU20 has been declining steadily since the 1990s despite reductions in fishing mortality. This DU was assigned a status of Endangered due to a 54% decline in abundance between 2003-2015, and the trend is expected to continue (COSEWIC Criterion A).
Early Summer	DU2 Bowron-ES	Endangered	The number of mature individuals in this population has been declining

Management Unit (MU)	Designatable Unit (DU) & Stock Alias	COSEWIC Status	Reason for Assessment
			since the mid-1950s. DU2 was assigned a status of Endangered due to a 60% decrease between 2003-2015 (COSEWIC Criterion A).
	DU14 North Barriere-ES	Threatened	Since 1980, there has been a continuous decline in the number of mature individuals in DU14. This DU was assigned a status of Threatened due to having less than 10,000 mature individuals, an estimated continuing decline in the number of mature individuals, and more than 95% of mature individuals are in one subpopulation (COSEWIC Criterion C). It is noted the original population was extirpated in the 1920s and was rebuilt from transplants from the Raft River.
	DU22 Taseko-ES	Endangered	The number of mature individuals returning to DU22 has declined considerably since the 1990s. The DU was assigned a status of Endangered due to a population decline of 84% between 2003-2015 (COSEWIC Criterion A), having less than 2,500 individuals, and more than 95% of mature individuals are part of a single subpopulation (COSEWIC Criterion C).
Summer	DU16 Quesnel-S	Endangered	DU16 was historically one of the most abundant Sockeye populations in the Fraser River, yet numbers have been declining consistently since 2000. This DU was assigned a status of Endangered following a 97% decrease in mature individuals between 2003-2015 (COSEWIC Criterion A).
	DU21 Takla-Trembleur-S (Late Stuart)	Endangered	DU21 has been declining steadily since the early 2000s yet removals from fishing has remained high. The number of mature individuals declined by 68% between 2003-2015 (COSEWIC Criterion A).
	DU24 Widgeon-RT	Threatened	The number of mature individuals within DU24 was relatively stable from 1950 to 1990, and then declined considerably to a minimum in 2000. Between 2003-2015 generations the number of fish has returned to pre-1990 abundances. This DU was assigned a status of Threatened due to the small population size (<1000 individuals; COSEWIC Criterion D).
Late	DU10 Harrison (U/S)-L (Weaver)	Endangered	The number of mature individuals increased from a low level in 1960 to a peak in 1980. Since then, the numbers have fluctuated in a

Management Unit (MU)	Designatable Unit (DU) & Stock Alias	COSEWIC Status	Reason for Assessment
			downward direction to reach a historical minimum. This DU was assigned a status of Endangered due to a 76% decline in the number of mature individuals between 2003-2015 (COSEWIC Criterion A).
	DU17 Seton-L (Portage Creek)	Endangered	The number of mature individuals in this DU was relatively stable from the mid-1970s to the late-1990s. Since this period numbers have declined considerably, and the DU was assigned a status of Endangered following an 88% decrease in mature individuals between 2003-2015 (COSEWIC Criterion A). It is noted the original population was extirpated in the early 20th century, and the current population originated from hatchery transplants from the Adams River.

1.2. LISTING AND RECOVERY BACKGROUND

Declining trends in abundance have been observed for FRS over the last several decades, and these declines were the main focus of the Cohen Inquiry into the declines of Sockeye salmon from the mid-1990's to 2009 (Cohen 2012a, 2012b, 2012c; Grant et al. 2019). Almost half of FRS stocks have been placed in the WSP Red status zone (Grant and Pestal 2012; DFO 2018a), and in November 2017, COSEWIC assessed the status of 24 DUs leading to eight DUs being assessed as Endangered, two as Threatened, five as of Special Concern, and nine as Not at Risk. Prior to the COSEWIC (2017a) assessment, DU6 (Cultus-L, Endangered; not covered in this RPA) is the only population in the Fraser River basin that had been previously assessed. In the fall of 2002, DU6 was emergency-listed and assigned a status of Endangered the following year in a formal assessment (COSEWIC 2003a). In October 2002, COSEWIC had also assessed the Sakinaw population of Sockeye Salmon (not part of the Fraser River group) as *Endangered* in an emergency assessment, which was confirmed by subsequent assessments conducted by COSEWIC in 2003, 2006, and 2016 (COSEWIC 2003b, 2006[1], 2016).

This RPA evaluates the status of nine DUs of Sockeye Salmon that spawn in the Fraser River drainage, which have been designated as either Threatened or Endangered by COSEWIC (2017a; Cultus Lake (DU6) assessed separately in DFO 2020b). Typically, when an RPA is undertaken, all 22 different elements are compiled into a single working paper for review to inform not only a listing decision under SARA, but subsequent recovery planning. Due to the number of DUs, this process was split into two working papers - this report addresses 16 of 22 elements outlined in the Terms of Reference for completion of RPAs for Aquatic Species at Risk (DFO 2014a), which includes:

1. summaries of FRS biology, abundance, distribution and life history parameters (Element 1-3);

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[1] COSEWIC 2006. COSEWIC Emergency assessment of the Sakinaw population of Sockeye Salmon *Oncorhynchus nerka*. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

2. descriptions of FRS habitat and residence requirements at all life stages (Element 4-7);
3. assessment and prioritization of threats and limiting factors to the survival and recovery of FRS (Element 8-11);
4. descriptions of suitable habitat supply and whether habitat requirements are met (Element 14);
5. discussions of scenarios for mitigation of threats and alternatives to activities (Element 16-18);
6. an allowable harm assessment to evaluate the maximum human-induced mortality and habitat destruction that the species can sustain without jeopardizing its survival or recovery (Element 22).

2. BIOLOGY, ABUNDANCE, DISTRIBUTION, AND LIFE HISTORY PARAMETERS

2.1. ELEMENT 1: SUMMARY OF SOCKEYE SALMON BIOLOGY

2.1.1. Adult morphology

Adult Sockeye Salmon have a slender, streamlined and silver-blue body with fine black specking on the back but lacking large dark spots (COSEWIC 2017a). Morphological features used for identification of Sockeye Salmon include: a dorsal fin with 11-16 rays; a small, slender and fleshy adipose fin; 13-18 anal fin rays; pelvic fins abdominal in position with 9-11 rays and a free-tipped fleshy appendage above the insertion point; pectoral fins with 11-21 rays; cycloid scales; gill rakers (29-43) that are long, rough, slender, and closely set on the first gill arch; an elongate body with moderate lateral compression; and in juveniles, the parr marks are oval and shorter than the diameter of the eye, and usually above the lateral line (Pauley et al. 1989).

During maturation, Sockeye Salmon undergo a distinct morphological change, with the head and tail becoming pale/olive green and the body turning brilliant red in colour. Male Sockeye develop large teeth, a pronounced hooked jaw (kype), and a small dorsal hump, while females largely retain their marine body shape (Burgner 1991).

2.1.2. Life history variation

Anadromous Sockeye Salmon can be divided into three life history variants based on their freshwater life history: “lake-type” Sockeye rear in lakes for one or more years in a nursery lake before migrating to sea; “ocean-type” Sockeye migrate downstream as subyearlings to estuarine or marine ecosystems after spending one winter in freshwater; and “river-type” Sockeye rear in riverine habitats for one to two years before migrating to sea as yearlings (Wood et al. 1987, 2008; Heifetz et al. 1989; Wood 1995). The vast majority of FRS populations are considered lake-type variants and rear in a variety of small to large lakes throughout the Fraser River watershed. Despite the river-type designation for DU24 Widgeon-RT, these fish migrate out into the marine environment as subyearlings, and are thus considered ocean-type variants. As such, throughout this document DU24 is hereby referred to as an ocean-type population. To our knowledge there are no true river-type Sockeye populations within the Fraser River basin. Once in the marine environment, Sockeye Salmon grow and mature for a variable amount of time (typically 2-3 years in the Fraser River watershed) before returning to spawn as adults (see next section for further discussion). In addition to anadromous variants of Sockeye, Kokanee are non-anadromous Sockeye Salmon (do not migrate to sea) that are only found in lakes (Gilbert 1913; Nelson 1968; COSEWIC 2017a).

2.1.3. Life cycle

Sockeye Salmon are anadromous and semelparous fish: they spawn and rear in freshwater, migrate to the ocean to mature, and then return to freshwater to spawn and die. FRS spawn in rivers, streams, and along lake foreshores throughout the Fraser River basin between July and January, yet spawning occurs most frequently in August and September (COSEWIC 2017a). Spawning begins with the construction of a redd by female Sockeye in substrates ranging from coarse sand to large rubble/boulders, where eggs are deposited to be fertilized by a male, and then covered with gravel by the female to incubate over winter. Redd construction occurs in depths ranging from 0.1 meters to 30 meters in temperatures ranging from approximately 7 to 14 degrees Celsius (Burgner 1991; Whitney et al. 2013). The duration of egg incubation and emergence timing is dependent on incubation temperatures and discharge, yet generally occurs between mid-April to mid-May (Burgner 1991; Macdonald et al. 1998). Sockeye eggs have the smallest average size of any Pacific salmon (Burgner 1991) yet vary between FRS DUs, with size of adult females and migration distance being the primary determinant for overall size (Linley 1993).

Lake-type Sockeye migrate to their nursery lakes upon emergence from spawning gravels, which often occurs after nightfall and in great densities (Quinn 2005). The newly emerged fry feed and grow in the littoral zone of lakes from early June through mid-July, before moving offshore where they remain in the open water of the lake until they migrate to sea as smolts (Morton and Williams 1990; COSEWIC 2017a). Between April and June, lake-type FRS migrate rapidly downstream from their rearing lakes to the Fraser River estuary (Clark et al. 2016), yet downstream movement can be influenced by the timing of ice break-up on the lake and subsequent water temperatures; extent and direction of wind action on the lake; and size, age, and physiological readiness of the smolts (Burgner 1991; DFO 2016; COSEWIC 2017a). Most FRS migrate northward from the Strait of Georgia in late May, with abundance tailing off late into June and July (Clark et al. 2016; Johnson et al. 2019). FRS then migrate northwest along the continental shelf until they reach wintering grounds in the Gulf of Alaska during late autumn and early December (Tucker et al. 2009; Welch et al. 2009; COSEWIC 2017a). Sockeye from DU7 (Francois-Fraser-S; not covered in RPA), DU21 (Takla-Trembleur-EStu), and DU22 (Takla-Trembleur-S) appear to leave the continental shelf somewhat earlier than all other populations (Tucker et al. 2009). Most FRS are lake-type variants, making up all but one of the DUs covered in this RPA (DU24 Widgeon-RT).

Ocean-type Sockeye fry disperse downstream into the lower Fraser River shortly after emergence, where they rear for up to 5 months or move immediately out into the Strait of Georgia (Birtwell et al. 1987; Macdonald et al. 2020). These fish remain in the Strait of Georgia for several months after all other Fraser Sockeye stocks have migrated out of this system, and will largely migrate out into the northeast Pacific and to the Gulf of Alaska via the southern Juan de Fuca Strait route, although a proportion also migrates out the northern Johnstone Strait route (Tucker et al. 2009; Beamish et al. 2016). Only a small proportion of FRS are ocean-type variants, with the only confirmed populations in the Fraser system being in Widgeon Creek (DU24) and the Harrison River (DU23, not covered in this RPA; Grant et al. 2011).

Adult FRS can range in age from three to six years, spending their first one to three winters in freshwater and their last one to three winters in the marine environment; however, most FRS (~80% total age composition) return to spawn as four year olds after spending two winters in the freshwater followed by two winters in the marine environment (age-4_2) (Grant et al. 2011; Macdonald et al. 2020). A smaller proportion (~20% total adult age composition) of FRS spend one extra winter in the marine environment and return to spawn as 5 year-olds (age-5_2; Grant et al. 2011). It should be noted that DU15 (Pitt-ES; not covered in this RPA) is unique in the Fraser system in that they predominately return to spawn as 5 year-old fish (~65% total run). FRS also have a small component of 3 year-old fish that return to spawn (age-3_2), referred to as precocious males (jacks) or females (jills), the latter of which are much less common. For all lake-type FRS DUs, a very small proportion of fish spend three winters in freshwater and varying lengths of time in the marine environment (ages: 4_3, 5_3, 6_3), yet there is evidence maturation appears to be occurring earlier as proportions of four year-olds relative to the other age classes has been increasing since the 1980s (Holt and Peterman 2004; Grant et al. 2010). Ocean-type variants (DU23 Harrison-RT, DU24 Widgeon-RT) return to spawn as either three or four year old fish (age-3_1 and age-4_1 respectively) yet for DU23 (not covered in this RPA) the proportion of recruits that return as three or four year olds is highly variable, with higher percentages of age-4 fish (~65%) returning during odd years when Pink Salmon are also spawning in this system (Grant et al. 2010, 2011).

FRS are broadly classified into four run-timing groups based upon timing of re-entry into coastal waters and their upstream spawning migration, and make up the four fisheries MUs listed in Table 1: Early Stuart (EStu), Early Summer (ES), Summer (S) and Late (L). The Early Stuart run consists of populations that spawn in tributaries to Stuart, Takla, and Trembleur, lakes, but the three remaining runs, early summer, summer, and late, are not geographically discrete and each contain populations from throughout the Fraser River drainage (Lapointe et al. 2003).

Each of the four groups arrives sequentially to coastal waters via either Johnstone or Juan de Fuca straits during the summer. The proportion of FRS travelling through Johnstone Strait varies annually, and the fraction of fish that migrate via Johnstone Strait is called the northern diversion rate (Folkes et al. 2018; Phung et al. 2020). Folkes et al. (2018) note that there was a significant trend towards increasing northern diversion rates between 1953-2014, but this trend has broken down in recent years likely due to changing conditions in the marine environment. While an analysis by Folkes et al. (2018) did not detect any significant differences in diversion rate across Sockeye Salmon cycle lines (from 1953-2014), and it is generally noted that diversion rate tends to be earlier in cycle years with higher relative abundance of early-timed run components and/or lower relative abundance of later-timed run components (Pacific Salmon Commission [PSC] Secretariat, pers. comm.). This variation across cycle lines is because of intra-annual trends in daily diversion rates where fish migrate more predominantly through Juan de Fuca Strait earlier in the season, and then daily diversion rates shift towards the north as the season progresses. As a result, early arriving stock groups tend to have lower annual northern diversion rates, than later-timed components (PSC Secretariat, pers. comm.). However, for a given date, the majority of stocks are assumed to experience the same diversion. The one notable exception is for the Harrison-Widgeon stock aggregate, which has been observed to migrate more predominantly around the southern end of Vancouver Island for a given day than other components of the run. On average, this results in a Harrison annual northern diversion rate which is roughly 70% of that observed for the non-Harrison components of the run (M. Hague, PSC, pers. comm.).

2.1.4. Diet

Newly emerged lake-type Sockeye fry feed almost exclusively in shallow (<10 m) littoral habitat in the spring and early summer and then move out into pelagic waters to feed until smoltification; however, this transition in feeding behaviour and diet varies between populations and is influenced by a suite of environmental conditions and competitive or predatory interactions (Burgner 1991). The diets of Sockeye fry in littoral habitats commonly consist of dipteran insects but may also include a variety of copepod and cladoceran species Burgner 1991). *Cyclops* is a common genera of copepod that are often the primary prey of lake-type Sockeye fry during the initial lake residence period in nursery lakes, prior to blooms of more preferable zooplankton species (i.e. February to May; (Burgner 1991; Clarke and Bennett 2002;

Beauchamp et al. 2004). When available, Sockeye fry feed heavily and preferentially on *Daphnia* spp. (Shortreed et al. 2001; Beauchamp et al. 2004) a common genera of cladocerans, yet will substitute other prey organisms if preferred prey are less abundant in a given year or season (Karpenko et al. 1998; Tyler 2001; Preikshot et al. 2010).

Juvenile FRS diets are highly diverse during early marine life. Price et al. (2013) report juvenile FRS diets in the Strait of Georgia and Johnstone Strait included members from the follow taxon: Copepoda, Brachyura, Oikopleura, Euphausiacea, Cnidaria, Cladocera, Cyclopoida, Harpacticoida, Polychaeta, Echinodermata, Mollusca, Pteropoda, Decapoda, Amphipoda, Insecta, Cumacea, and others (eggs, fish). Anderson et al. (2021) more recently reported the most common prey items found in juvenile FRS between Queen Charlotte Sound to Dixon Entrance were amphipods and euphausiids. Research has shown different feeding strategies dependant on location during the early marine period, with FRS diets in the warmer and fresher waters of the Discovery Islands being dominated by meroplankton, cladocerans, and larvaceans, while FRS diets in the cooler and saltier waters of Johnstone Strait were dominated by large calanoid copepods (James 2019). The authors identify, however, that while juvenile FRS exhibit strong selective feeding behaviours, this selection appears to be based on size (prey items > 2 mm), rather than on prey type (James 2019).

Adult Sockeye continue to feed on zooplankton in the ocean, but also prey on larval and small adult fish, squid, and crustaceans such as hyperiids (Karpenko et al. 2007). There has been a considerable shift in Sockeye diet in the North Pacific Ocean in the last several decades; sampling in the 1980s showed energetically superior planktonic species such as hyperiids and euphausiids dominated Sockeye diets, while in the 2000s, juvenile squid, forage fish, and other lower-energy prey have become more prevalent (Karpenko et al. 2007). Further discussion of shifting FRS prey distribution can be found in section 4.1.11.1.

Table 2. Summary of FRS life-history, migration timing, age-at-maturation, and presence of cyclic abundance.

Designatable Unit	Life-History Variant	Age-at-Maturation	Cyclic Abundance
DU2 Bowron-ES	Lake-Type	4	Yes
DU10 Harrison U/S-L	Lake-Type	4	No
DU14 North Barriere-ES	Lake-Type	4	No
DU16 Quesnel-S	Lake-Type	4	Yes
DU17 Seton-L	Lake-Type	4	No
DU20 Takla-Trembleur-EStu	Lake-Type	4	Yes
DU21 Takla-Trembleur-S	Lake-Type	4	Yes
DU22 Taseko-ES	Lake-Type	4	Unknown
DU24 Widgeon-RT	Ocean-Type[1]	3	Unknown

[1] DU24 Widgeon-RT is classified as a river-type stock, yet is in fact an ocean-type variant; Sockeye from this DU migrate to sea as subyearlings, while river-type Sockeye overwinter for 1 or more years in freshwater streams and migrate to sea as yearlings.

2.2. ELEMENT 2: EVALUATION OF RECENT SOCKEYE SALMON ABUNDANCE TRAJECTORY, DISTRIBUTION, AND NUMBER OF POPULATIONS

2.2.1. Distribution and number of populations

The Fraser River houses one of the largest spawning complexes of Sockeye Salmon in North America with FRS spawning in over 150 natal areas throughout the watershed (Burgner 1991; Pestal et al. 2012). The nine FRS DUs covered in this RPA are widely distributed throughout the lower (DU10 Harrison (U/S)-L; DU24 Widgeon-RT), middle (DU16 Quesnel-S; DU17 Seton-L; DU20 Takla-Trembleur-ES; DU21 Takla-Trembleur-S; DU22 Taseko-ES); and upper (DU2 Bowron-ES) Fraser River basin, in addition to the Thompson River drainage (DU14 North Barriere-ES). Three of the DUs (DU10, DU17, and DU24) have single spawning sites, while the remaining 6 DUs spawn in multiple locations. It should be noted that for many DUs water clarity and depth of spawning likely impair observations of habitat use by the fish, and so estimates of the spatial extent of spawning based on these observations should be considered minimum estimates (de Mestral Bezanson et al. 2012; COSEWIC 2017a). The freshwater spawning distribution of FRS is described in COSEWIC (2017a) as the index of area of occupancy (IAO), calculated by overlaying the extent of spawner occurrence within a given DU with a grid of 2 x 2 km cells, and summing the total area in which spawning was observed between 2008 and 2011 (de Mestral Bezanson et al. 2012). For all FRS DUs the extent of occurrence in the marine environment is greater than 20,000 km^2 because high seas monitoring programs have demonstrated that their ocean migration extends at least as far north as 60^0 and west as 180^0 (Myers et al. 1996; COSEWIC 2017a), and is not reported to avoid repetition.

Table 3 in the next section lists the persistent spawning streams within each DU used for abundance trend analysis, yet does not necessarily contain all FRS-bearing streams within the DU. For a complete list of streams within each FRS DU, refer to Appendix A.

2.2.2. Trends in productivity and abundance

Productivity has been declining since at least the 1990s for all Endangered, Threatened, and Special Concern FRS DUs for which stock-recruit data is available (DFO 2020a). The productivity of other Sockeye populations in Southeast Alaska, coastal British Columbia (BC), and Washington have similarly declined over time, and these declines have intensified in recent years (Peterman and Dorner 2012; Ruggerone and Connors 2015). It is possible that this shared decrease in productivity has resulted from a coincidental combination of simultaneous processes related to freshwater habitat degradation, contaminants, pathogens, predators, and (or) food supply that have each independently affected individual stocks or small groups of stocks (Peterman and Dorner 2012). However, the large spatial scale of synchronous declines in productivity across populations in the southern range suggest that poor survival in the shared marine environment may be the driver of these declines (Peterman and Dorner 2012; Freshwater et al. 2018; Rosengard et al. 2021). Conversely, northern populations of Sockeye Salmon tend to exhibit opposite trends in productivity (Peterman and Dorner 2012) and are more weakly associated with large-scale environmental drivers (Malick et al. 2017), suggesting northern populations may currently be in a regime where freshwater processes at fine spatial scales are the principal driver of variation in productivity rather than poor marine survival (Freshwater et al. 2018). There are many anthropogenic threats and natural limiting factors within the freshwater and marine environments that can influence FRS productivity, and are discussed in detail in sections 8 and 10, respectively. Spawner abundances for FRS are estimated annually based on an intensive survey program that involves many different organizations, and covers all parts of the Fraser Basin (Pestal et al. In Press). FRS enumeration is conducted using a variety of techniques including fence counts, mark-recapture studies, hydroacoustic systems, and aerial/ground surveys. These survey programs vary considerably between systems depending on a number of factors including water depth, turbidity, and accessibility to spawning habitat. As mentioned in the above section, six of the DUs covered in the RPA contain multiple spawning sites within the DU area, some of which are not surveyed for Sockeye abundance, or have been inconsistently surveyed through time. This results in abundance estimates for some DUs that are based off a single, or few streams within a larger DU area, and may not be representative of the DU as a whole.

FRS are currently assessed as forecasted DUs, with a time series of both spawner and recruit estimates, or miscellaneous DUs, with a time series of spawner estimates only (Pestal et al. In Press). Seven of nine DUs considered in the RPA (DU2 Bowron-ES, DU10 Harrison U/S-L, DU14 North Barriere-ES, DU16 Quesnel-S, DU17 Seton-L, DU20 Takla-Trembleur-EStu, DU21 Takla-Trembleur-S) have a long time series of stock-recruit data that can be used to model future abundance trajectories (see DFO 2020; Pestal et al. In Press). For DU22 Taseko-ES and DU24 Widgeon-RT, only spawner estimates exist and are based off a limited number of visual surveys and/or carcass counts, with no stock-recruit data to perform similar quantitative analyses as the aforementioned seven DUs. Further to this, DU22 and DU24 are low abundance DUs and there is a higher degree of uncertainty associated with estimating the run size of smaller stocks (i.e. numerical limitation of small samples sizes, co-migration of stocks with much higher abundances), and conducting visual surveys at lower abundances.

Grant et al. (2011) assigned one of five data quality classifications to the estimates of spawner abundance from each FRS DU, based on the survey methods, conditions, and frequency:

1. Poor: an estimate with poor accuracy due to poor counting conditions, few surveys (one or two in a given year), incomplete time series, etc.
2. Fair: an estimate using two or more visual inspections that occur during peak spawning where fish visibility is reasonable; methodology and data quality varies across the time series in terms of good to poor quality
3. Good: four or more visual inspections with good visibility
4. Very good: an estimate of high reliability using mark recapture methods, hydroacoustic methods, or near-complete fence counts that have relatively high accuracy and precision. Visual surveys that have been calibrated with local fence programs
5. Excellent: an unbreached fence estimate with extremely high accuracy given an almost complete census of counts.

Table 3 provides DU-specific summaries of FRS enumeration programs including principle spawning locations, data quality, survey methods, and spawning extent (IAO). We note that in some cases survey methods have changed since Grant et al. (2011) assigned the aforementioned data quality rankings, and the rankings have been updated to reflect current efforts (see Table 3). The subsequent set of plots (Figures 3-18) display abundance estimates and trends in productivity for each DU using updated data since the COSEWIC (2017a) assessment and Part 1 of the RPA (DFO 2020a), and now includes the 2014-2016 brood years. For DUs in which stock-recruit data were available, future abundance projections are provided for the three-generation assessment time period. A brief summary of key data points, DU survey coverage, and data issues are also provided with the abundance time series for each DU. For further information regarding data collection, treatment, and sources of uncertainty refer to Pestal et al. (In Press).

Table 3. Persistent spawning sites, survey methods, data quality, and Index of Area of Occupation (IAO) for FRS DUs assessed in RPA. Note that not all spawning sites are represented here; for a complete list of streams where FRS spawning has been recorded refer to Appendix A.

Designatable Unit	Persistent Spawning Sites	Data Quality	Stock-Recruit Data	Survey Methods	IAO (km^2)
DU2 Bowron-ES	Bowron R	Good	Yes	Aerial Fence (2 years only)	16
DU10 Harrison-L (Weaver)	Weaver Ch Weaver Cr	Good	Yes	Peak Live & Cumulative Dead Mark Recapture Carcass Census Fence	4
DU14 North Barriere-ES (Fennel Cr)	Barriere R (upper)	Good	Yes	Peak Live & Cumulative Dead	20
DU16 Quesnel-S	Horsefly R Mitchell R McKinley Cr Penfold Cr	Very Good	Yes	Peak Live & Cumulative Dead Mark Recapture Fence Hydroacoustic	352
DU17 Seton-L (Portage)	Portage Cr	Good	Yes	Peak Live & Cumulative Dead	20
DU20 Takla-Trembleur-EStu	Forfar Cr Gluske Cr O'Ne-ell Cr Van Decar Cr	Good[2]	Yes	Peak Live & Cumulative Dead Fence (1988-2009)	428
DU21 Takla-Trembleur-S	Middle R Tachie R Kazchek Cr Kuzkwa Cr	Good - Very Good[3]	Yes	Peak Live & Cumulative Dead Mark Recapture Fence	164
DU22 Taseko-ES	Taseko L	Fair	No	Carcass Census	24
DU24 Widgeon-RT	Widgeon Sl	Good	No	Peak Live & Cumulative Dead	4

2.2.2.1. DU2 Bowron-ES

The Bowron system contains four main spawning sites (Bowron River, Pomeroy, Huckey, and Sus Creeks) that have been consistently assessed since 1948, yet almost all of the observed abundance is in the upper Bowron River. Huckey, Pomeroy and Sus creeks were rolled up into Upper Bowron River estimates pre-2004; independent estimates have been reported since 2004. Surveys were done by fence until 1963, then switched to helicopter-based visual estimates from 1964 to present. The 1995 visual survey was complemented by a counting fence, which produced an expansion factor about 60% larger than that typically used for Fraser Sockeye (2.9 vs 1.8). This indicates estimates from 1964 to 1994 may be biased low (Schubert 2007). In addition, there is inconsistency in the expansion index applied to visual estimates through the time series - the standard 1.8 was used until 1998, then changed to 2.8 in 1999 based on the 1995 fence calibration; the time series pre-1999 was not adjusted; therefore, estimates pre-1999 may be biased low or estimates since 1999 are biased high (the latter is considered more likely). Due to limited access to carcasses in recent years (low abundance and

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[2] DU20 Takla-Trembleur-EStu was previously assigned a data quality ranking of "Very Good" by Grant et al. (2011). In recent years (2010-2021) data quality has been reduced to "Good" following the removal of counting fences, and switching to visual surveys and expansion factors to estimate escapement (see section 2.2.2.6).

[3] DU21 Takla-Trembleur-S was previously assigned a data quality ranking of "Good" by Grant et al. (2011). Data quality for DU21 changes from "Good" to "Very Good" depending on the year, as on dominant cycle-lines mark-recapture studies are conducted to estimate escapement (see section 2.2.2.7)

high predation), estimates of sex ratio and spawning success have been assumed (50/50 sex ratio, 100% spawn success). Abundance estimates for this DU have higher uncertainty due to the small run size, less frequent surveys and impacts of high discharge on detection probability during aerial surveys in some years.

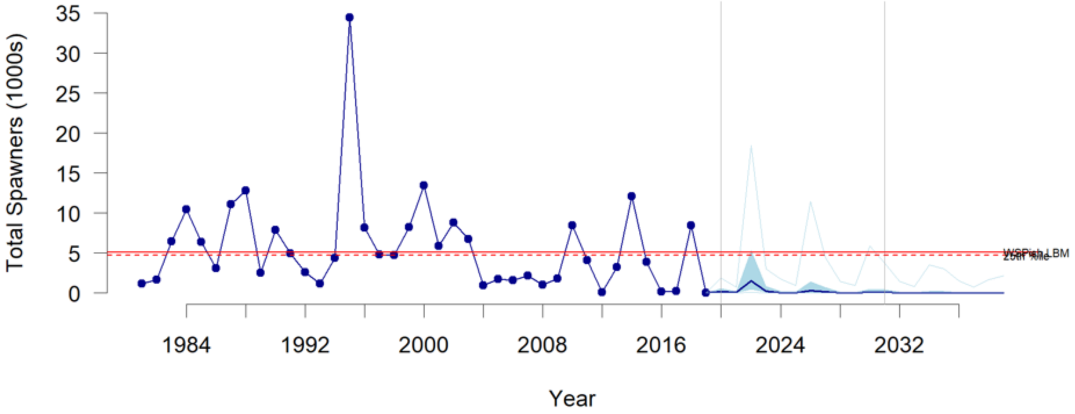

Figure 3. Estimates of total spawners for DU2 Bowron-ES (1981-2020) and modelled abundance projections using the methods described in Part 1 of RPA (DFO 2020a). The solid red line represents the lower WSP benchmark for the DU; the dashed red line represents the 25th percentile of historical abundance for the DU; the grey vertical lines represent the three generation assessment time-period of the RPA; the shaded blue portion represents the 25th to 75th percentiles for abundance in the forward projections; the solid blue line represents the median abundance in the forward projections; and the faint blue lines represent the 95th percentile of abundance for forward projections.

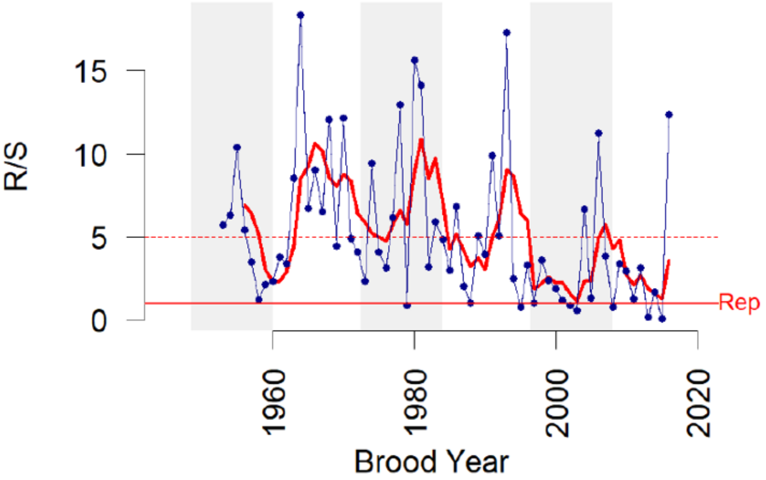

Figure 4. Estimates of annual productivity (recruits per spawner; R/S) and the running average (red line) for DU2 Bowron-ES. Reference lines show 1 R/S (i.e. replacement, marked as Rep) and 5 R/S.

2.2.2.2. DU10 Harrison (U/S)-L

There are two main sites within this DU, Weaver channel and Weaver Creek. Historically Weaver Creek was assessed with mark-recapture surveys, visual counts, or an enumeration fence in different years. Since 2004, only visual surveys have been used. Weaver Channel was exclusively assessed at the channel diversion fence. No data issues were identified with the stock-recruit data presented in Figure 5.

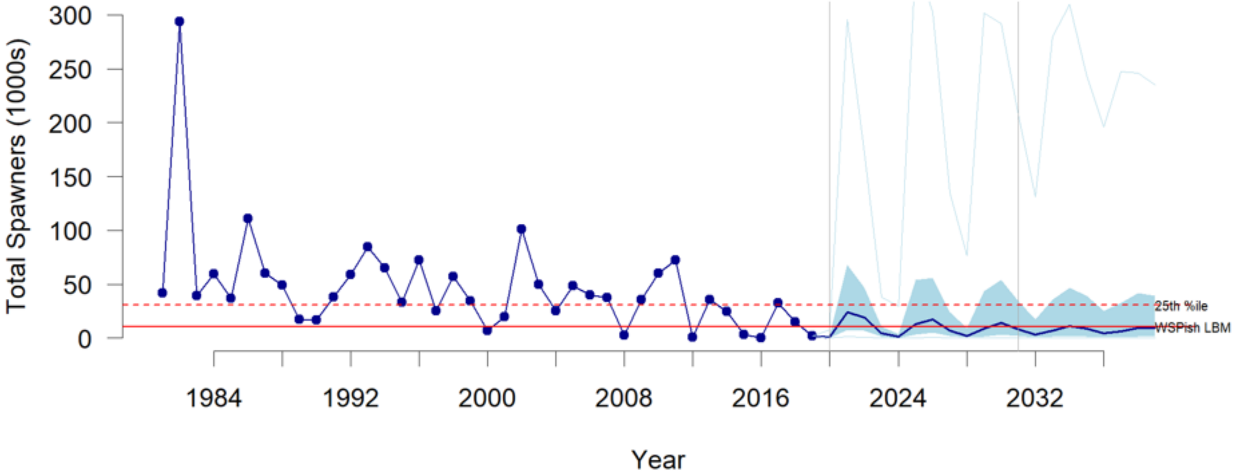

Figure 5. Estimates of total spawners for DU10 Harrison U/S-L (1981-2020) and modelled abundance projections using the methods described in Part 1 of RPA (DFO 2020a). The solid red line represents the lower WSP benchmark for the DU; the dashed red line represents the 25th percentile of historical abundance for the DU; the grey vertical lines represent the three generation assessment time-period of the RPA; the shaded blue portion represents the 25th to 75th percentiles for abundance in the forward projections; the solid blue line represents the median abundance in the forward projections; and the faint blue lines represent the 95th percentile of abundance for forward projections.

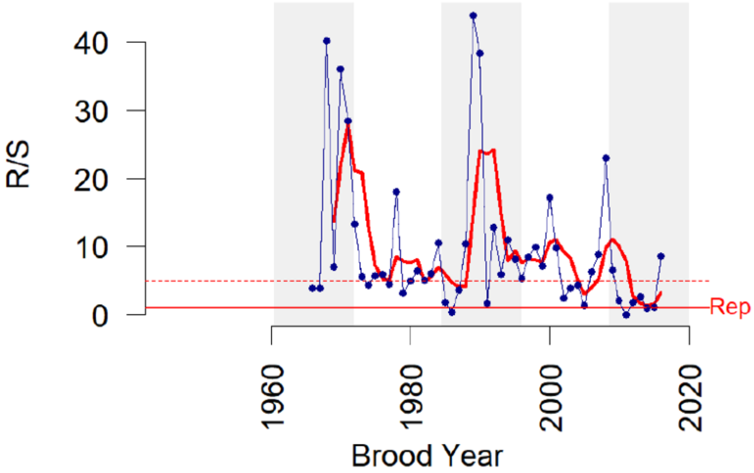

Figure 6. Estimates of annual productivity (recruits per spawner; R/S) and the running average (red line) for DU10 Harrison (U/S)-L. Reference lines show 1 R/S (i.e. replacement, marked as Rep) and 5 R/S.

2.2.2.3. DU14 North Barriere-ES

This DU contains two main spawning sites in the Upper Barriere River and Harper Creek. The Upper Barriere is the dominant site and contributes almost all of the of the total annual escapement to this system (>98% on average), and has been assessed with a mix of visual and fence counts. Harper Creek has been visually assessed on an annual basis since 1998. No data issues were identified with the time series presented in Figure 7.

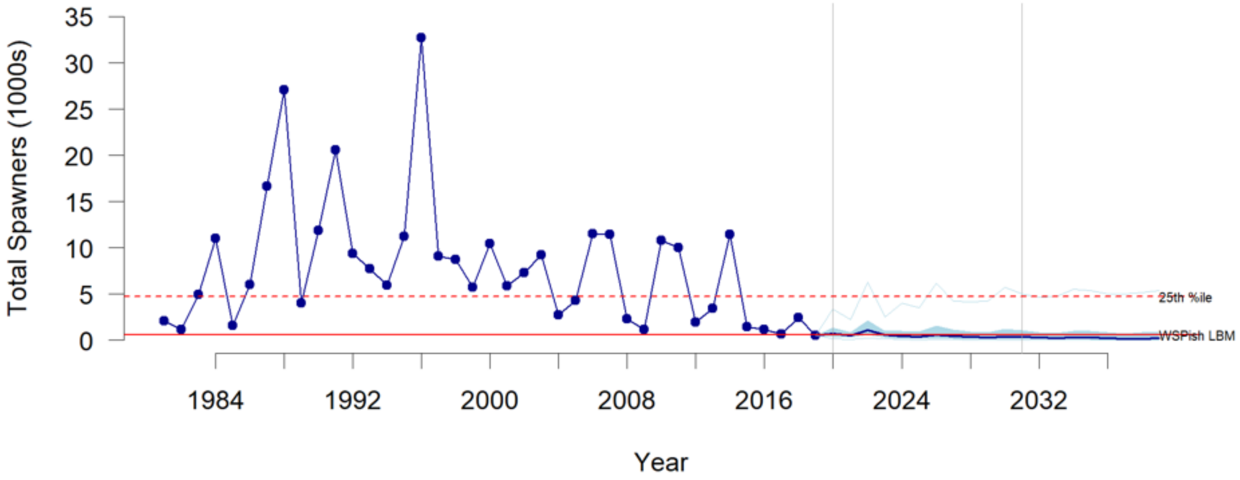

Figure 7. Estimates of total spawners for DU14 North Barriere-ES (1981-2020) and modelled abundance projections using the methods described in Part 1 of RPA (DFO 2020a). The solid red line represents the lower WSP benchmark for the DU; the dashed red line represents the 25th percentile of historical abundance for the DU; the grey vertical lines represent the three generation assessment time-period of the RPA; the shaded blue portion represents the 25th to 75th percentiles for abundance in the forward projections; the solid blue line represents the median abundance in the forward projections; and the faint blue lines represent the 95th percentile of abundance for forward projections.

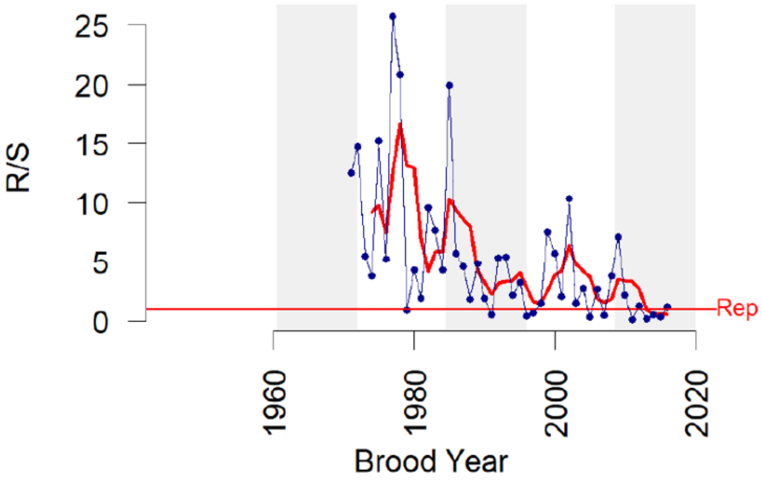

Figure 8. Estimates of annual productivity (recruits per spawner; R/S) and the running average (red line) for DU14 North Barriere-ES. Reference lines show 1 R/S (i.e. replacement, marked as Rep) and 5 R/S.

2.2.2.4. DU16 Quesnel-S

Many spawning sites are contained within the Quesnel system. Tributaries with substantial abundances at some point in recent decades are Cameron Creek, Horsefly River (including spawning channel), McKinley Creek, Mitchell River and Penfold Creek. These key sites are assessed consistently with peak-live cumulative-dead visual counts for most of the time series, with some variations in data collection through time. Mitchell River was assessed with peak-live cumulative-dead visual surveys until 1989, then switched to mark-recapture and hydroacoustic methods in 2009. Horsefly River was initially assessed with peak-live cumulative-dead visual surveys until 1979, and now includes a mark-recapture program. Horsefly River was also estimated using hydroacoustic methods (DIDSON) in 2010. In most years since 2014, high precision hydroacoustic methods have been used to estimate aggregate escapement for the entire DU at a site located in the Quesnel River at the outlet of Quesnel Lake. This has been coupled with peak-live cumulative-dead visual surveys at individual sites within the DU area to allow for continued time series of spawner abundance at these sites. Individual site estimates are calibrated using the relatively precise hydroacoustic estimate for the aggregate and the proportion of the total live count contributed by each site. There are three years in the more recent time series with missing/incomplete escapement estimates (2002, 2005 and 2006) due to funding shortfalls.

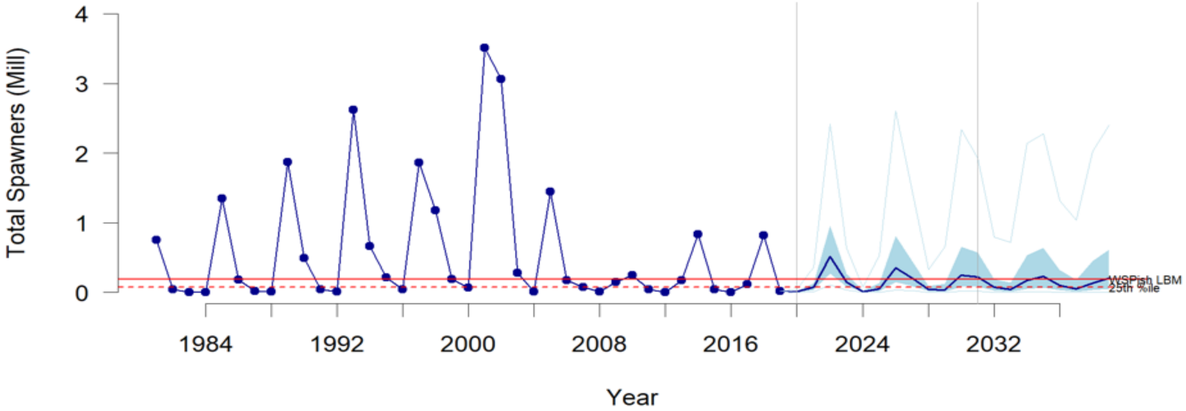

Figure 9. Estimates of total spawners for DU16 Quesnel-S (1981-2020) and modelled abundance projections using the methods described in Part 1 of RPA (DFO 2020a). The solid red line represents the lower WSP benchmark for the DU; the dashed red line represents the 25th percentile of historical abundance for the DU; the grey vertical lines represent the three generation assessment time-period of the RPA; the shaded blue portion represents the 25th to 75th percentiles for abundance in the forward projections; the solid blue line represents the median abundance in the forward projections; and the faint blue lines represent the 95th percentile of abundance for forward projections.

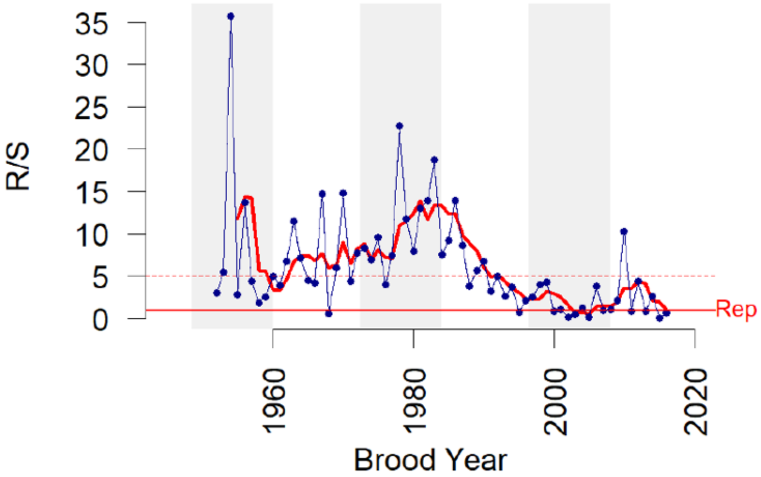

Figure 10. Estimates of annual productivity (recruits per spawner; R/S) and the running average (red line) for DU16 Quesnel-S. Reference lines show 1 R/S (i.e. replacement, marked as Rep) and 5 R/S.

2.2.2.5. DU17 Seton-L

There is a single major spawning site for this DU in Portage Creek, which has been assessed using peak-live cumulative-dead visual survey methods throughout the time series presented.

There have also been two years of observations of spawners at a location on Seton Lake (Lost Valley Creek shore spawners) in 2010 and 2014. No data issues were identified with the time series presented in Figure 11.

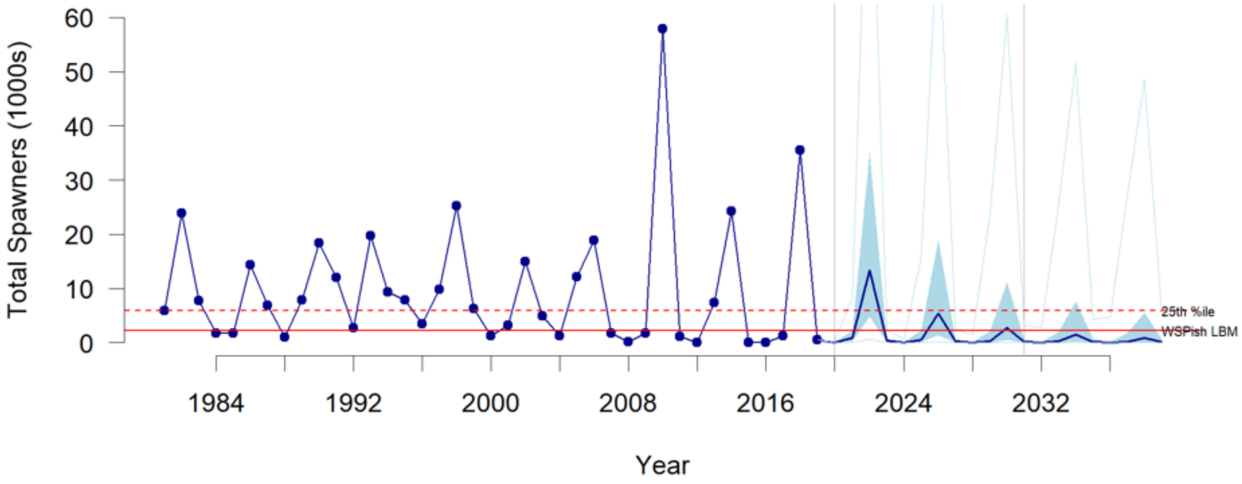

Figure 11. Estimates of total spawners for DU17 Seton-L (1981-2020) and modelled abundance projections using the methods described in Part 1 of RPA (DFO 2020a). The solid red line represents the lower WSP benchmark for the DU; the dashed red line represents the 25th percentile of historical abundance for the DU; the grey vertical lines represent the three generation assessment time-period of the RPA; the shaded blue portion represents the 25th to 75th percentiles for abundance in the forward projections; the solid blue line represents the median abundance in the forward projections; and the faint blue lines represent the 95th percentile of abundance for forward projections.

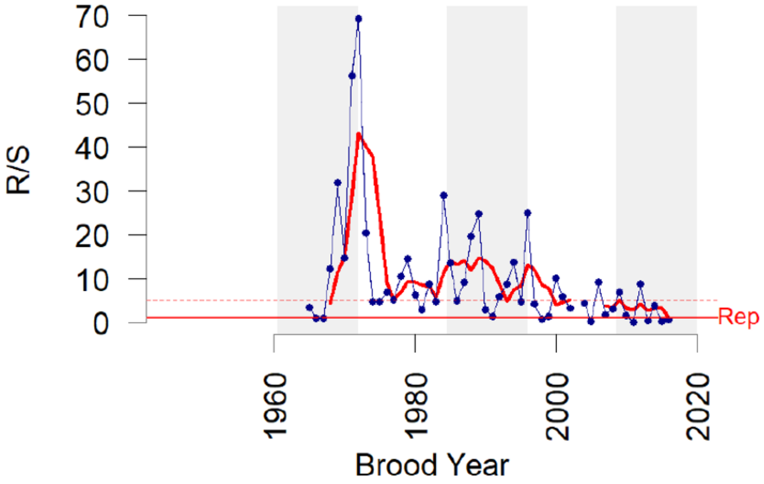

Figure 12. Estimates of annual productivity (recruits per spawner; R/S) and the running average (red line) for DU17 Seton-L. Reference lines show 1 R/S (i.e. replacement, marked as Rep) and 5 R/S.

2.2.2.6. DU20 Takla Trembleur-EStu

This DU contains 48 spawning sites in the Stuart system with at least 1 verified spawner observation, yet survey effort may change on an annual basis depending on spawner abundance. On any given year at least one, and generally multiple surveys (on 4- or 7-day cycles) are conducted in all streams where spawners are present, and only areas that appear to have negligible or zero spawners are excluded. There are 4 sites that are assessed consistently with visual surveys (Forfar, Gluske, O'Ne-ell, and Van Decar creeks). Between 1988-2009, visual surveys in these streams were paired with complete counts at counting fences to provide a dataset of accurate expansion factors to be applied to these and other streams comprising the DU.

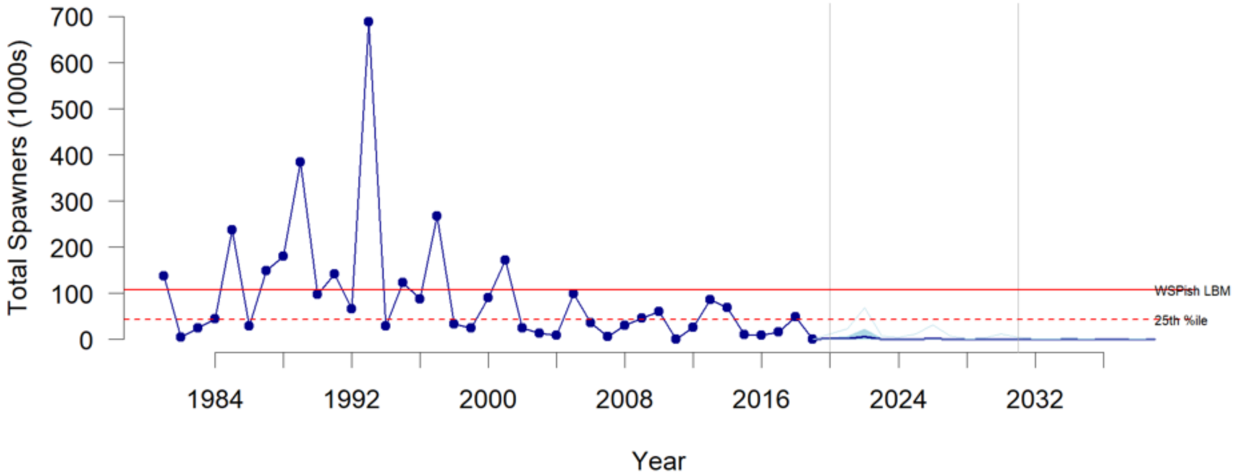

Figure 13. Estimates of total spawners for DU20 Takla-Trembleur-EStu (1981-2020) and modelled abundance projections using the methods described in Part 1 of RPA (DFO 2020a). The solid red line represents the lower WSP benchmark for the DU; the dashed red line represents the 25th percentile of historical abundance for the DU; the grey vertical lines represent the three generation assessment time-period of the RPA; the shaded blue portion represents the 25th to 75th percentiles for abundance in the forward projections; the solid blue line represents the median abundance in the forward projections; and the faint blue lines represent the 95th percentile of abundance for forward projections.

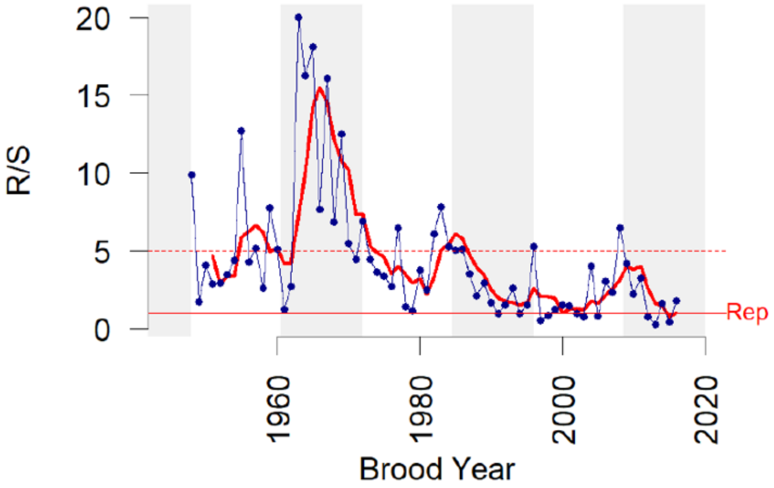

Figure 14. Estimates of annual productivity (recruits per spawner; R/S) and the running average (red line) for DU20 Takla-Trembleur-EStu. Reference lines show 1 R/S (i.e. replacement, marked as Rep) and 5 R/S.

2.2.2.7. DU21 Takla Trembleur-S

This DU includes multiple spawning sites within the Trembleur and Stuart lakes system. The vast majority of spawning occurs at four sites: Kazcheck Creek, Kuzkwa River, Middle River, and Tachie River. Kazcheck Creek has been assessed visually throughout the time series. Kuzkwa Creek was assessed using peak-live cumulative-dead survey methods throughout the time series, except in years between 1997-2005 when mark-recapture assessments occurred on the Tachie River and an enumeration fence was used on Kuzkwa, which is a tributary of Tachie. Middle River was assessed using mark-recapture methods on dominant years and peak-live cumulative-dead surveys on the three off-cycle years. Since 2005, Middle River escapement estimates have been based on visual surveys. The Tachie River was assessed using mark-recapture surveys on dominant years, and peak live cumulative dead surveys on other years. From 1992-2012, mark-recapture assessments were conducted on 2 of 4 cycle lines. In 2013, the programs returned to mark-recapture assessments on 1 in every 4 years (on the 2021 cycle line). It's difficult to differentiate between Late Stuart and Stellako Sockeye with DNA, therefore the assignment of catch and en route mortality to total recruits are more uncertain than for other stocks with more distinctive DNA. There is also difficulty enumerating large/dark/tannic rivers such as Tachie and Middle rivers visually, therefore visual estimates of Tachie and Middle River are likely biased low.

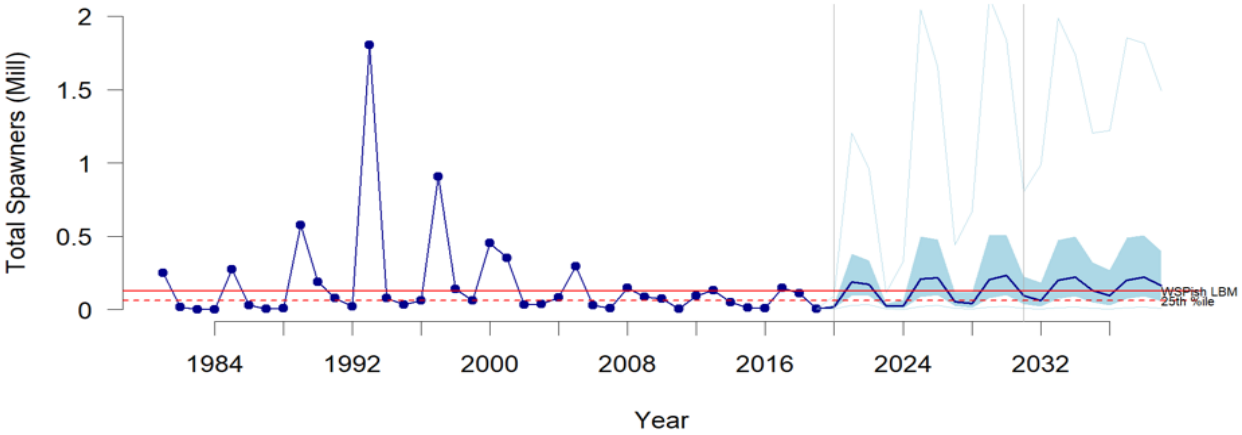

Figure 15. Estimates of total spawners for DU21 Takla-Trembleur-S (1981-2020) and modelled abundance projections using the methods described in Part 1 of RPA (DFO 2020a). The solid red line represents the lower WSP benchmark for the DU; the dashed red line represents the 25th percentile of historical abundance for the DU; the grey vertical lines represent the three generation assessment time-period of the RPA; the shaded blue portion represents the 25th to 75th percentiles for abundance in the forward projections; the solid blue line represents the median abundance in the forward projections; and the faint blue lines represent the 95th percentile of abundance for forward projections.

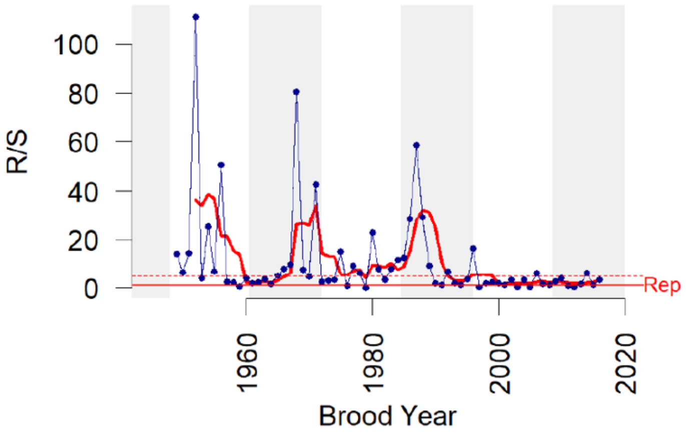

Figure 16. Estimates of annual productivity (recruits per spawner; R/S) and the running average (red line) for DU21 Takla-Trembleur-S. Reference lines show 1 R/S (i.e. replacement, marked as Rep) and 5 R/S.

2.2.2.8. DU22 Taseko-ES

Abundance estimates for this DU are based on visual surveys of lake spawners along the west shore of Taseko Lake; very few spawners have been observed in tributaries to Taseko Lake. Taseko watershed is a glacial and turbid system that prevents effective visual surveys. Carcass expansion factors are used for many years but bear predation hinders carcass recovery efforts. Hydroacoustic methods have been employed in recent years, but to date have not provided full coverage of fish arriving to spawning grounds. Due to the low abundance and limited access to carcasses in recent years, estimates of sex ratio and spawning success have been assumed (50/50 sex ratio, 100% spawn success). Escapement estimates for this DU should be considered minimums and not used as indices.

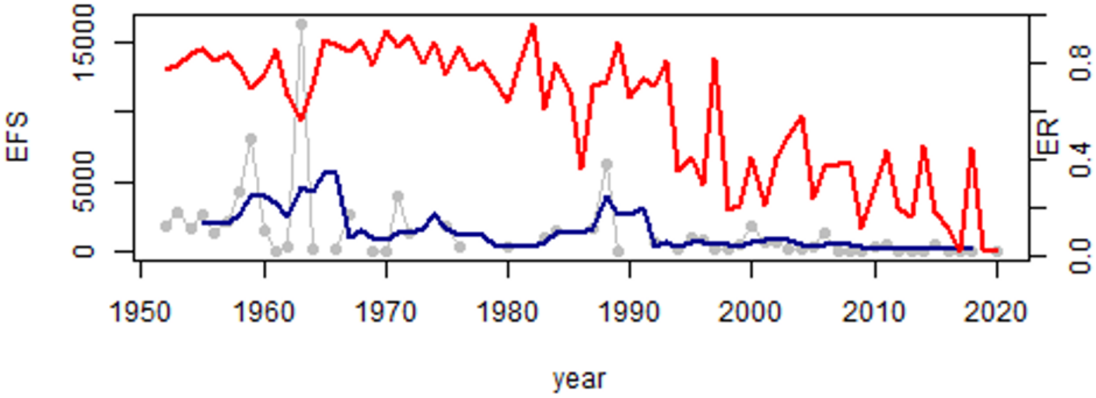

Figure 17. Time series of Effective Female Spawners for DU22 Taseko-ES. The grey line represents annual effective spawners; the blue line represents the 1 generation running average; the exploitation rate for the Early Summer MU is provided as a proxy exploitation rate, and is represented by the red line.

2.2.2.9. DU24 Widgeon-RT

Widgeon Creek and Widgeon Slough comprise a small watershed that flows into the Pitt River just below the outlet of Pitt Lake. Sockeye spawn in a single area of Widgeon Slough during high tides. There is only one record of Sockeye spawning in Widgeon Creek, observed in 2014. Abundance is estimated on peak-live cumulative-dead visual surveys, but there is uncertainty in these estimates as carcasses are often washed out of the system during tidal changes, in addition to high levels of predation by bears and a variety of avian species. The peak-live cumulative-dead method is not appropriate for this DU as it does not exhibit the typical normal bell curve of arrival and die off exemplified by most other FRS populations that typically display a distinct peak. Estimates of spawner abundance are likely underestimates but can likely be used as an index of the true abundance.

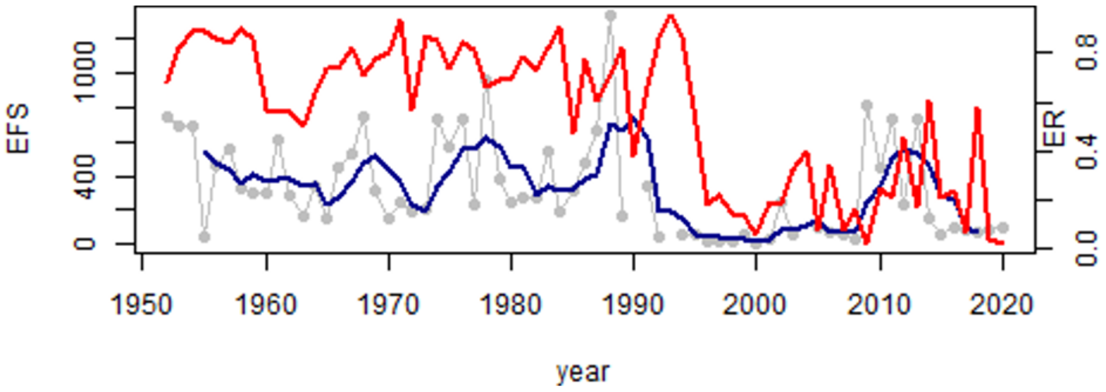

Figure 18. Time series of Effective Female Spawners for DU24 Widgeon-RT. The grey line represents annual effective spawners; the blue line represents the 1 generation running average; the exploitation rate for the Summer MU is provided as a proxy exploitation rate, and is represented by the red line.

2.3. ELEMENT 3: RECENT LIFE HISTORY PARAMETERS

Most FRS DUs have long-established stock assessment programs that collect life history information such as length, age, and fecundity during adult migration and carcass recovery. For some DUs this is either not possible due to low run sizes and difficulties recovering carcasses, challenges with genetic stock identification, or sampling is not conducted regularly for logistic reasons (e.g. funding, sampling in remote locations). In some cases, opportunistic sampling is done in conjunction with other stock assessment and management objectives, yet this does not necessarily occur on an annual basis. Further to this, for cyclic stocks (e.g. DU16 Quesnel-S, DU20 Takla-Trembleur-EStu, DU21 Takla-Trembleur-S), dominant years are often over-represented due to the difficulty in collecting carcasses in years of low abundance. Table 4 displays length-at-age and fecundity data for FRS DUs covered in the RPA over the past three generations, where available.

There is evidence indicating a declining trend in size- and age-at-maturity in Pacific salmon stocks across their range. Recent work by Oke et al. (2020) reported shared size declines across Pacific salmon stocks starting in the mid 1980s followed by recovery in the 1990’s, and a more abrupt decline beginning in 2000 and intensifying after 2010. The same pattern has also been observed for FRS over the time period; in 2019 and 2020, lengths recorded on spawning grounds were among the lowest on record (Latham et al. In Press). In addition to the overall declining trend in size, there appears to be a biennial fluctuation in size-at-age for FRS with smaller fish returning in odd-numbered years, and a later maturity for Sockeye with odd-numbered brood years (Latham et al. In Press). Several factors may be influencing this pattern including high abundances of Pink Salmon driven in part by high levels of hatchery production (discussed in section 4.1.2.3), increasing ocean temperatures, and changes in the abundance and composition of prey resources in the marine environment (discussed in section 4.1.11.1). Declining trends of older and large fish are important to note for species recovery, because these life history parameters can influence productivity and recovery potential through reduced fecundity and egg survival (Healey 2001; Quinn et al. 2011). Delayed maturity may also introduce additional harms to FRS through an additional year of exposure to threats in the marine environment, potentially reducing the speed of evolutionary response to climate change (Latham et al. In Press). Reduced salmon size also decreases the per-capita transport of marine-derived nutrients into terrestrial ecosystems, with important implications for a wide array of ecological processes including riparian productivity and biodiversity (Hocking and Reynolds 2011; Oke et al. 2020) that may indirectly impact FRS and other resident aquatic species within DUs.

Table 4. Average fecundity by age class and length-at-age data over the past 3-generations for FRS DUs covered in RPA. In many cases fecundity data were unavailable (DU2, DU14, DU17, DU22, DU24), or unavailable over the entire 3-generation time period presented (DU16 data for 2010, 2013, 2014 only; DU20 no data for 2010, 2011, 2013, 2014; DU21 data for 2008, 2009, 2012, 2013, 2017 only). Length-at-age is reported in mm from the postorbit of the eye to the hypural plate (POH); data were excluded for infrequently observed age classes of FRS.

MU	DU		Average Fecundity by Age Class			Length-at-Age (POH)								
						Male					Female			
			4_2	5_2	**	3_1	3_2	4_1	4_2	5_2	3_1	4_1	4_2	5_2
Early Stuart	DU20 Takla-Trembleur-EStu	MEAN	3480	4070	-	-	345	-	485	522	-	-	476	513
		N	97	29	-	-	40	-	2766	655	-	-	2963	557
		95% CL	(3390,3570)	(3830,4310)	-	-	(338,352)	-	(484,486)	(520,524)	-	-	(475,476)	(511,515)
Early Summer	DU2 Bowron-ES	MEAN	-	-	-	-	-	-	485	524	-	-	467	507
		N	-	-	-	-	-	-	347	63	-	-	367	56
		95% CL	-	-	-	-	-	-	(482,487)	(519,528)	-	-	(465,469)	(500,513)
	DU22 Taseko-ES	MEAN	-	-	-	-	-	-	472	510	-	-	451	495
		N	-	-	-	-	-	-	64	15	-	-	60	10
		95% CL	-	-	-	-	-	-	(467,477)	(498,522)	-	-	(445,456)	(478,513)
	DU14 North Barriere-ES	MEAN	-	-	-	-	336	-	472	522	-	-	452	498
		N	-	-	-	-	5	-	468	199	-	-	611	213
		95% CL	-	-	-	-	(313,359)	-	(470,474)	(519,525)	-	-	(450,453)	(495,500)
Summer	DU21 Takla-Trembleur-S	MEAN	3040	3920	-	-	348	-	454	491	-	-	452	487
		N	101	4	-	-	209	-	3398	725	-	-	3796	511
		95% CL	(2950,3140)	(3080,4770)	-	-	(345,351)	-	(453,455)	(489,492)	-	-	(451,453)	(485,489)
	DU16 Quesnel-S	MEAN	3310	4030	-	-	357	-	490	537	-	-	475	519
		N	84	30	-	-	254	-	3199	504	-	-	3403	750
		95% CL	(3210,3410)	(3880,4180)	-	-	(355,359)	-	(490,491)	(535,539)	-	-	(474,476)	(517,520)
	DU24 Widgeon-RT	MEAN	-	-	-	413	-	452	-	-	407	454	-	-
		N	-	-	-	248	-	150	-	-	235	149	-	-
		95% CL	-	-	-	(410,416)	-	(449,456)	-	-	(404,409)	(450,457)	-	-
Late	DU17 Seton-L	MEAN	-	-	-	-	354	-	491	531	-	-	477	518
		N	-	-	-	-	36	-	536	40	-	-	558	23
		95% CL	-	-	-	-	(351,358)	-	(489,493)	(525,538)	-	-	(476,479)	(508,528)
	DU10 Harrison U/S-L*	MEAN	-	-	3850	-	369	-	490	527	-	-	474	510
		N	-	-	119	-	170	-	1243	473	-	-	1107	574
		95% CL	-	-	(3730,3970)	-	(365,372)	-	(489,492)	(525,529)	-	-	(473,476)	(508,512)

* DU10 has a long-term data series of length and fecundity to which new fecundity data is added as obtained, a regression analysis preformed, and the current year's fecundity obtained from entering the average length of female into the regression formula. Additional challenges to obtaining fecundity samples is that skeins are often loose already when arriving at the channel; some samples noted as loose are included in the data presented; there is no corresponding age data.

3. HABITAT AND RESIDENCE REQUIREMENTS

3.1. ELEMENT 4: HABITAT PROPERTIES THAT SOCKEYE SALMON NEED FOR SUCCESSFUL COMPLETION OF ALL LIFE-HISTORY STAGES

3.1.1. Spawning and egg incubation habitat

Most Sockeye populations spawn in river systems that have a snow-dominated hydrograph, with a spring or early summer freshet followed by a period of stable or declining flows during the late spawning and incubation (Mote et al. 2003a). This late period of relatively stable conditions is important for spawning success, as large fluctuations in flows and temperature during spawning and egg incubation can affect the quality and quantity of Sockeye habitat. There are also populations in the lower reaches of the Fraser River Basin that spawn in systems with mixed rain- and snow-dominated hydrographs that are under tidal influence (i.e. DU24 Widgeon-RT and DU23 Harrison-RT; not covered in RPA).

Sockeye Salmon spawning begins with the construction of a redd, which functions to protect the eggs buried within them while providing suitable environmental conditions for development. Female Sockeye dig redds in gravel by using rapid undulations of her tail fin to hydraulically excavate a pit in the streambed, flushing a portion of the fine sediment into the water column to be carried downstream and mobilizing coarser sediment a short distance into a dune-like mound called a tailspill (Burner 1951; Buxton et al. 2015b). Redd construction occurs in depths ranging from 0.1 to 30 m, in substrates ranging from coarse sand to large rubble or boulders (Burgner 1991; Whitney et al. 2013). Successful incubation of salmon eggs depends on physical characteristics at the redd, the most important being water temperature, dissolved oxygen, and sedimentation (COSEWIC 2017a). Optimum spawning temperatures range from 10.6 and 12.2°C, incubation temperatures for successful hatching range from 4.4 to 13.3°C, and at least 5.0 mg/L dissolved oxygen is required for successful incubation of eggs (Reiser and Bjornn 1979). FRS often experience temperatures that exceed these optima; the resulting impacts are discussed further in section 4.1.11.3. Excessive amounts of sand and silt in the gravel can hinder fry emergence, even though the embryos may develop and hatch normally (COSEWIC 2003). Low or high flows, freezing temperatures, siltation, predation and disease can reduce egg survival (COSEWIC 2017a). Eggs within the redd hatch into juvenile Sockeye called alevins, which remain in the gravel to develop prior to emergence. Alevins move within the interstitial spaces between substrate particles in the redd, and during this period they are particularly vulnerable to the presence or deposition of fine sediments. When the yolk sack has been completely absorbed by the alevin, Sockeye emerge from the gravel as fry and migrate to freshwater foraging and rearing habitat. During this period FRS require stable, temperatures, dissolved oxygen, and minimal sediment inputs.

3.1.2. Fry and juvenile rearing habitat

For lake-type variants, newly emerged fry migrate into rearing habitat within their nursery lake where they occupy the littoral zone from late April to a maximum of mid-July, before moving offshore to the open water of the lake where they remain until outmigration to the ocean (COSEWIC 2017). The majority of the freshwater rearing period for Sockeye, typically 8-10 months, or about 70% of their freshwater residency period, occurs offshore within the deeper water (pelagic area) of the lake (Gilhousen and Williams, 1989). Ocean-type variants migrate downstream to the lower Fraser River area shortly after emergence from spawning gravels, where they rear for several weeks before migrating out into the Strait of Georgia (COSEWIC 2017a). Juvenile lake-type FRS require nursery lake habitat with adequate temperatures, dissolved oxygen, and food supply to complete this life-stage. Ocean-type FRS also require these factors but are more reliant on hydrological conditions and access to side-channels and sloughs during their extended rearing period in the lower Fraser.

3.1.3. Juvenile freshwater outmigration habitat

Lake-type FRS migrate rapidly out of their nursery lakes into the Fraser River, and out into the Strait of Georgia, generally occurring over a period of one to two months (Burgner 1991; DFO 2016; COSEWIC 2017a). Conversely, ocean-type FRS migrate downstream shortly after emergence from the gravel, and rear for a short period of time in the lower Fraser River area before migrating out into the Strait of Georgia (COSEWIC 2017a). Most studies have observed Sockeye Salmon rapidly transiting estuaries (Furey et al. 2015), yet there is some evidence that juveniles from distant populations (e.g. Alaska) have an extended occupancy within estuarine habitat (Simmons et al. 2013).

The timing of juvenile FRS outmigration into the Strait of Georgia is estimated from two smolt surveys conducted in the lower Fraser River at Mission, and 60 km upstream of the Fraser River outlet to the southern Strait of Georgia (Grant et al. 2018). All lake-type FRS are intercepted at Mission with the exception of DU15 Pitt-ES (not covered in RPA). The majority of FRS smolts leave the Fraser River and enter the Strait of Georgia between mid-April to late-May, and most have left the strait by mid-June (Johnson et al. 2019). FRS have been shown to exhibit differences in smolt outmigration timing among DUs, however this varies by year and no clear annual patterns of consistent timing for particular stocks have been identified (DFO 2014b, 2015a, 2016; Neville et al. 2016; Grant et al. 2018). Ocean-type DUs (DU24 Widgeon-RT; DU23 Harrison-RT (latter not covered in this RPA)) are largely excluded from smolt surveys due to project timing (Grant et al. 2018). The only published information on ocean-type FRS smolt outmigration is based on trawl surveys conducted in the Strait of Georgia (1998 to 2010). The majority of ocean-type FRS were found to enter the ocean approximately eight weeks after most lake-type FRS in mid-July, consistent with the understanding that ocean-type stocks take longer to reach the ocean from their spawning grounds, possibly delaying in sloughs in the Fraser River (Birtwell et al. 1987; Beamish et al. 2010, 2016; Grant et al. 2018).

3.1.4. Ocean rearing habitat

Following their entrance into the ocean, lake-type FRS (all DUs assessed in this RPA except DU24 Widgeon-RT) spend a variable period of time in the Strait of Georgia before beginning their northward migration either along the mainland coast, or along the east side of the Gulf Islands (Groot and Cooke 1987; Tucker et al. 2009; Welch et al. 2009; Neville et al. 2013; Beacham et al. 2014a; Beamish et al. 2016; Clark et al. 2016). Residence time for lake-type FRS stocks has been estimated to be between 20-59 days in the Strait of Georgia, and it has been suggested larger-sized fish initiate their northward migration earlier than their smaller counterparts (Preikshot et al. 2012; Beacham et al. 2014b, 2014a; Freshwater et al. 2016a, 2016b). Seine surveys indicate lake-type FRS are present in the Strait of Georgia between May and August, with the highest proportion of juveniles caught in June (Beacham et al. 2014). Migration and residence time within the Strait of Georgia is not well understood for ocean-type stocks, as most surveys have been conducted in the spring and summer when more abundant lake-type stocks are present (Beacham et al. 2014a; Beamish et al. 2016; Grant et al. 2018). The majority of ocean-type FRS migrate out into the northeast Pacific via the southern Juan de Fuca Strait with a small proportion migrating north through Johnstone Strait, and FRS that migrate through the northern route spend considerably longer in the Strait of Georgia ecosystem (July to September) when compared to lake-type populations (Tucker et al. 2009; Beacham et al. 2014a, 2014b; Beamish et al. 2016). Our limited understanding of ocean-type stocks has been identified as a knowledge gap for future research (see Appendix C)

There is limited knowledge surrounding migration timing or residence time of juvenile FRS in the Discovery Islands after they exit the Strait of Georgia, and what little is known mostly pertains to lake-type FRS populations (Grant et al. 2018). Residence time in this area is particularly uncertain, as estimates are generated using peak migration timing, acoustic tagging studies and theoretical optimal cruising speeds for juvenile salmon (Grant et al. 2018). The few available studies indicate lake-type FRS are found in the Discovery Islands between late May through to July, with peak migration occurring between May 23 and June 19 (Johnson 2016; Neville et al. 2016). There is currently no estimate of the migration timing of ocean-type FRS through the Discovery Islands (Grant et al. 2018); however, ocean-type FRS are thought to migrate through the northern route in the fall (Beacham et al. 2014a; Beamish et al. 2016). During this life stage FRS require prey in sufficient quantities, and predation during outmigration to the open ocean may be significant (see section 4.1.8.2, and 4.3.2).

Upon reaching the Gulf of Alaska, FRS are thought to rear south of Alaska during the winter and migrate to areas further offshore for the summer, where they feed and grow for up to three years before migrating to their natal spawning grounds in the Fraser River watershed (Walter et al. 1997; Grant et al. 2018).

3.1.5. Adult freshwater migratory habitat

In freshwater, each DU experiences a unique combination of temperatures and flows, with a greater likelihood of extreme discharge events occurring during the early runs (e.g. DU2 Bowron-ES, DU20 Takla-Trembleur-EStu, DU22 Taseko-ES) and temperature extremes during the summer runs (e.g. DU16 Quesnel-S, DU21 Takla-Trembleur-S; Patterson et al. 2007). High water temperatures have been shown to cause reductions in cardiorespiratory system function that may impede migration (Eliason et al. 2011). For Sockeye Salmon in general, water temperatures above ~18°C increase enroute and pre-spawn mortality through a variety of mechanisms including swimming ability, susceptibility to disease, stress, and heat shock. Stream discharge varies considerably between DUs due to their unique physical stream attributes (rapids, falls, canyons, human-made fishways, weirs); in some cases, low flows may result in physical limits to fish passage, while high flows may generate velocity barriers that reduce or prohibit upstream migration. Discharge thresholds have been proposed for different DUs depending on the location of spawning grounds. For example, Early Stuart FRS (DU20) are thought to have higher discharge thresholds (8,500 m^3/s) when compared to Early Summer DUs such as Bowron and Taseko (DU2 and DU22; 6,000 m^3/s; Macdonald et al. 2010).

Depending on their return timing and distance to spawning grounds, FRS require different hydrological conditions and buffering from high temperatures during their upstream migration. Temperature and physiological limits/impacts are discussed in greater detail for each DU in sections 4.1 and 4.3.

3.2. ELEMENT 5: INFORMATION ON THE SPATIAL EXTENT OF THE AREAS IN SOCKEYE SALMON DISTRIBUTION THAT ARE LIKELY TO HAVE THESE HABITAT PROPERTIES

3.2.1. Freshwater habitat distribution

The freshwater distribution of each FRS DU is presented in the following maps. Mapped distributions are based on spawner surveys, which may underestimate the full extent of the distribution of FRS due to constraints in conducting annual spawner surveys over such a broad geographical area. Data for FRS DU areas were obtained from the Government of Canada

Open Government Portal[4], and freshwater GIS data was obtained from the BC Government geographic data and services data catalogue[5].

3.2.1.1. DU2 Bowron-ES

Figure 19. Map of DU2 Bowron-ES, illustrating the DU boundary, known spawning sites within the DU, and spawning density. Spawning density is depicted as Low (green), Medium (yellow), High (red), or Unknown (purple) based on DFO stock assessment observations between 2000-2020.

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[4] Government of Canada Open Government Portal.

[5] Government of BC Geographic data and services.

3.2.1.2. DU10 Harrison (U/S)-L

Figure 20. Map of DU10 Harrison (U/S)-L, illustrating the DU boundary, known spawning sites within the DU, and spawning density. Spawning density is depicted as Low (green), Medium (yellow), High (red), or Unknown (purple) based on DFO stock assessment observations between 2000-2020.

3.2.1.3. DU14 North Barriere-ES

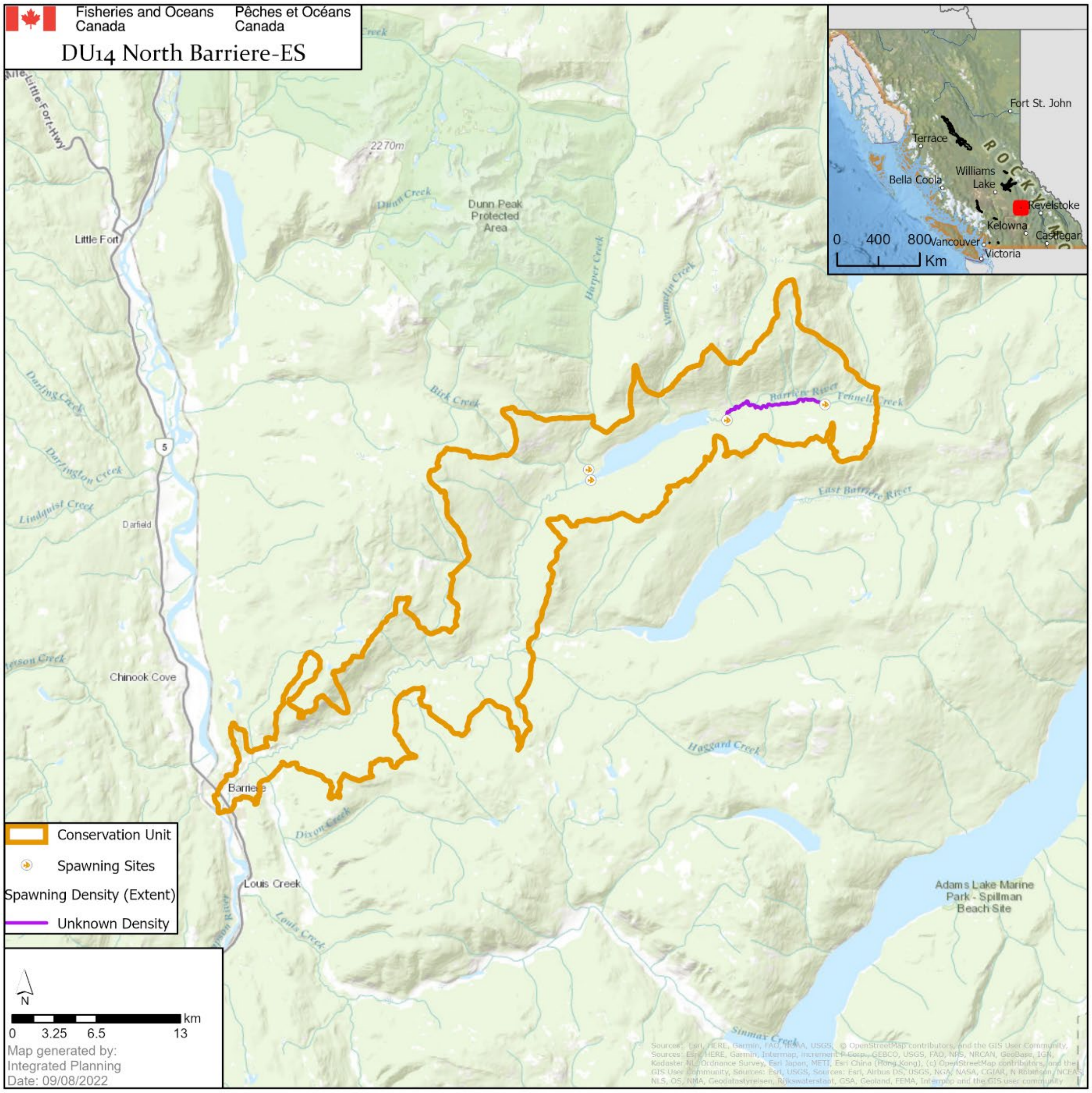

Figure 21. Map of DU14 North Barriere-ES, illustrating the DU boundary, known spawning sites within the DU, and spawning density. Spawning density is depicted as Low (green), Medium (yellow), High (red), or Unknown (purple) based on DFO stock assessment observations between 2000-2020.

3.2.1.4. DU16 Quesnel-S

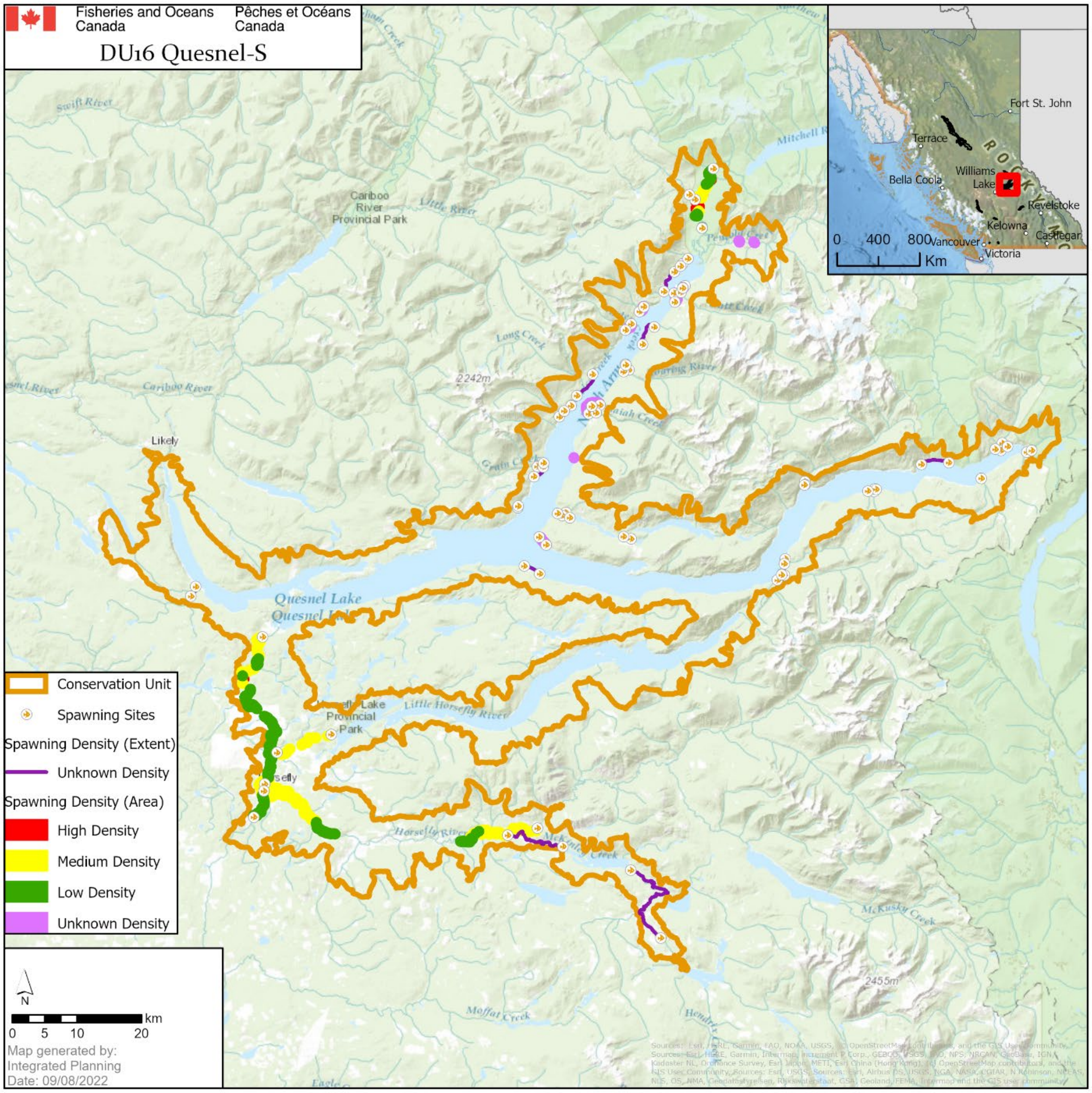

Figure 22. Map of DU16 Quesnel-S, illustrating the DU boundary, known spawning sites within the DU, and spawning density. Spawning density is depicted as Low (green), Medium (yellow), High (red), or Unknown (purple) based on DFO stock assessment observations between 2000-2020.

3.2.1.5. DU17 Seton-L

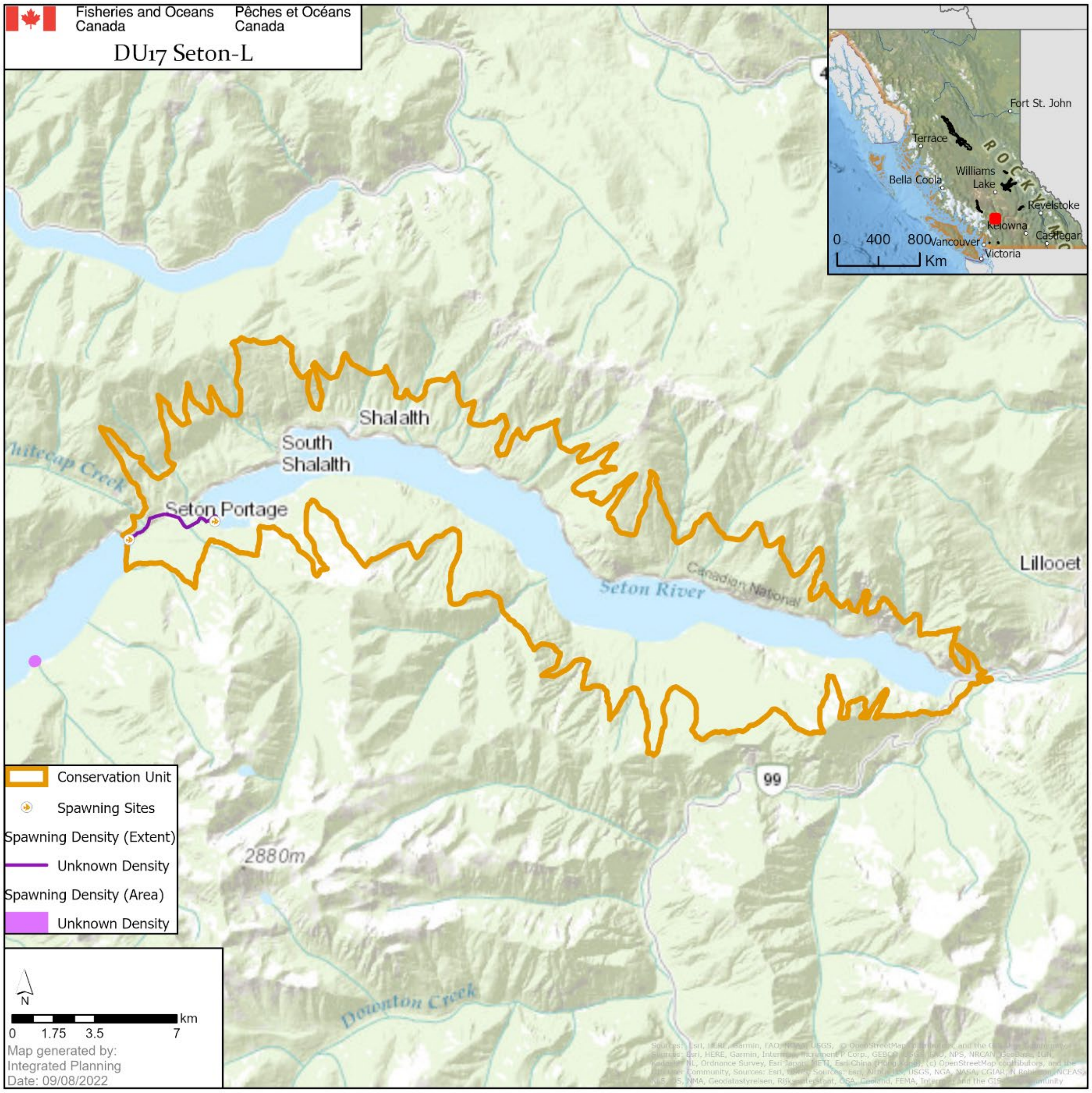

Figure 23. Map of DU17 Seton-L, illustrating the DU boundary, known spawning sites within the DU, and spawning density. Spawning density is depicted as Low (green), Medium (yellow), High (red), or Unknown (purple) based on DFO stock assessment observations between 2000-2020.

3.2.1.6. DU20 Takla-Trembleur-EStu

Figure 24. Map of DU20 Takla-Trembleur-EStu, illustrating the DU boundary, known spawning sites within the DU, and spawning density. Spawning density is depicted as Low (green), Medium (yellow), High (red), or Unknown (purple) based on DFO stock assessment observations between 2000-2020.

3.2.1.7. DU21 Takla-Trembleur-S

Figure 25. Map of DU21 Takla-Trembleur-S, illustrating the DU boundary, known spawning sites within the DU, and spawning density. Spawning density is depicted as Low (green), Medium (yellow), High (red), or Unknown (purple) based on DFO stock assessment observations between 2000-2020.

3.2.1.8. DU22 Taseko-ES

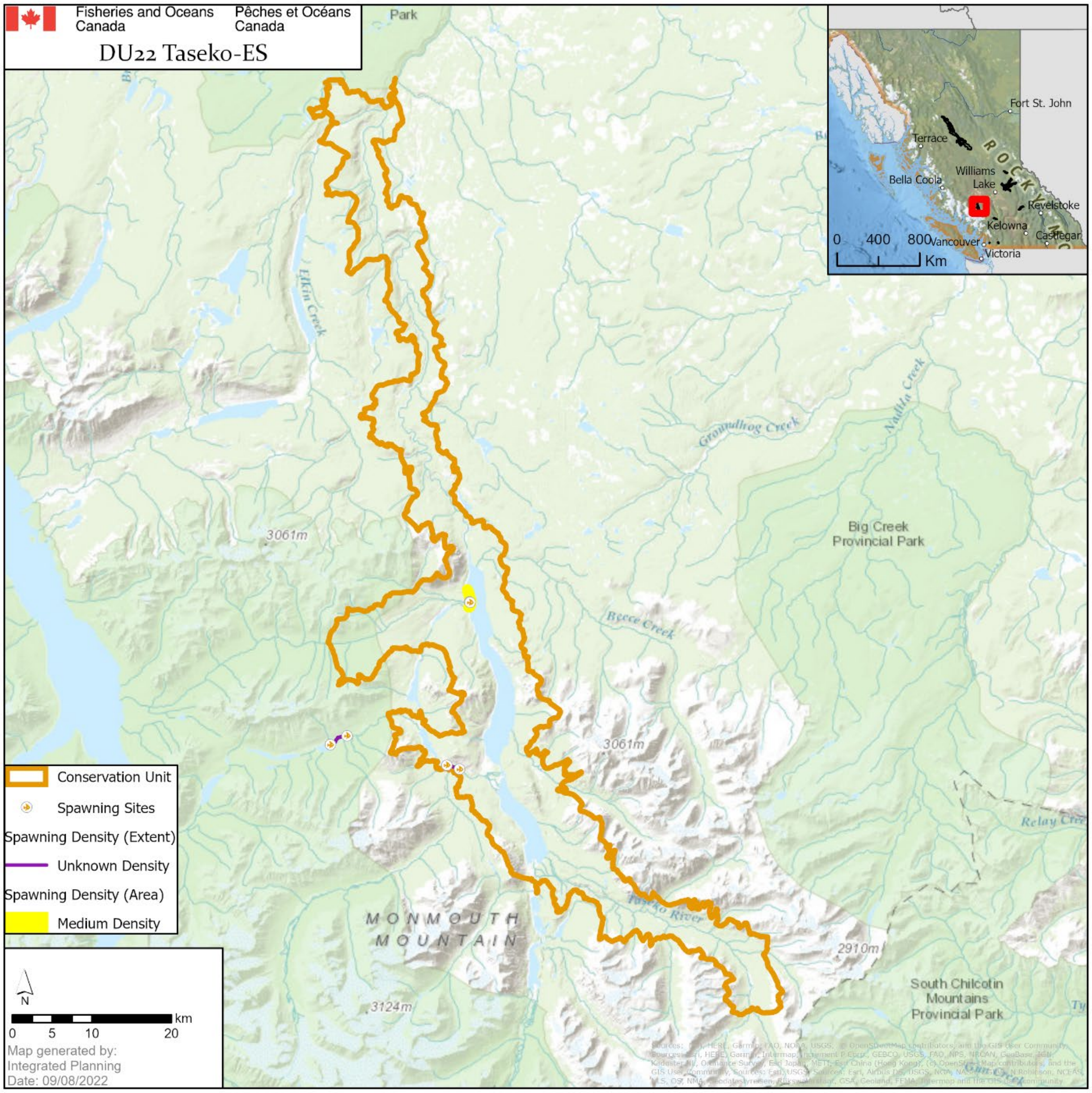

Figure 26. Map of DU22 Taseko-ES, illustrating the DU boundary, known spawning sites within the DU, and spawning density. Spawning density is depicted as Low (green), Medium (yellow), High (red), or Unknown (purple) based on DFO stock assessment observations between 2000-2020.

3.2.1.9. DU24 Widgeon-RT

Figure 27. Map of DU24 Widgeon-RT, illustrating the DU boundary, known spawning sites within the DU, and spawning density. Spawning density is depicted as Low (green), Medium (yellow), High (red), or Unknown (purple) based on DFO stock assessment observations between 2000-2020.

3.2.2. Marine distribution

There is limited data available on FRS movements and distribution once they leave freshwater, yet it is presumed that upon reaching the Gulf of Alaska, FRS rear south of Alaska during the winter and migrate to areas further offshore for the summer, where they feed and grow for up to three years before migrating to their natal spawning grounds in the Fraser River watershed (Walter et al. 1997; Grant et al. 2018).

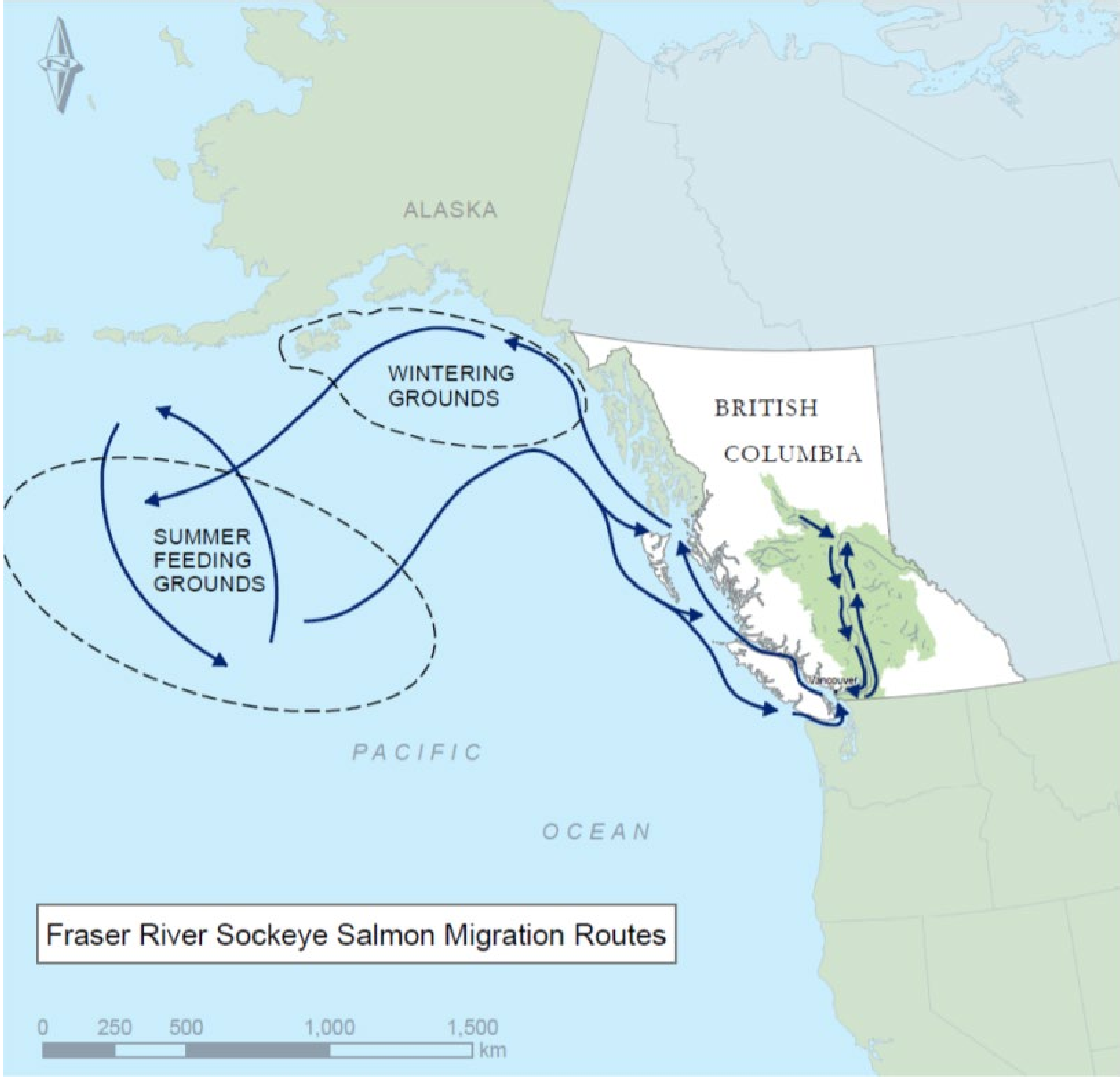

Figure 28. Presumed FRS migration routes and ocean distribution. Source: (Cohen 2012c).

3.3. ELEMENT 6: PRESENCE AND EXTENT OF SPATIAL CONFIGURATION CONSTRAINTS

3.3.1. Hydroelectric dams

There are two major hydroelectric developments that impact FRS covered in this RPA: the Kenney Dam on the headwaters of the Nechako River; and Seton and Terzaghi dams (Bridge-Seton hydroelectric complex) near the confluence to the mainstem Fraser and Seton rivers.

The Nechako River is regulated by Kenney Dam, which was constructed in the early 1950s to power the Alcan aluminium smelter in Kitimat, BC. Impounded water upstream of Kenney Dam is diverted from Nechako Reservoir to the coastal Kemano River watershed outside of the Fraser River basin (Déry et al. 2012). Flow regulation downstream of the dam involves release of water from the Nechako reservoir into the Cheslatta River system approximately 9 km downstream of Kenney Dam. The impacts on local ecosystems in the Nechako River basin were significant post-construction of Kenney dam, with large areas of land either flooded or drained leading to the displacement or impoundment of a number of fish (and other animal) species. The dam continues to threaten FRS that transit the lower reaches of the Nechako River (DU20 Takla-Trembleur-EStu, DU21 Takla-Trembleur-S), as cold water diverted from the system leads to low flows and potentially high stream temperatures. There are currently mitigations in place to reduce stream temperatures in the lower Nechako (discussed in detail in section 4.1.7.2), yet temperature effects have been identified and continue to threaten FRS returning to spawn in the Stuart drainage.

The Seton and Bridge Rivers were highly modified by hydroelectric development in the mid 20th century. The Bridge River was originally impounded in 1948 through the construction of the Mission Dam (renamed to Terzaghi Dam in 1965), where water is diverted from the Bridge River to Seton lake to generate hydropower (Melville et al. 2015). BC Hydro constructed a tunnel to allow water to flow from the Bridge system into Seton Lake, and Seton Dam was built to divert water into a 3.8 km long canal that delivers water to the hydroelectric power station on the Fraser River, 1.2 km downstream of the confluence with the Seton River (Roscoe et al. 2010). These infrastructures collectively make up the Bridge-Seton hydroelectric complex that impact FRS within the Seton watershed (DU17 Seton-L; see section 4.1.7.2. for discussion of impacts).

3.3.2. Landslides

There have been several major landslides in recent years that have impacted FRS, including events at Meager Creek (tributary to Lillooet River), Whitecap Creek (tributary to Portage Creek), and near Big Bar in the mainstem Fraser. These events can lead to partial or complete barriers to migration or cause ongoing sedimentation or smothering effects that can impact egg and juvenile incubation and rearing. These events and their impacts on FRS are discussed in further detail in section 4.1.10.1.

3.3.3. Floodplain connectivity

Floodplain connectivity in the lower Fraser River has been drastically reduced by agricultural, industrial, and residential development, in addition to the many flood control structures to protect these developments such as dikes, flood gates, and tide boxes. These flood control structures have led to the majority of wetland habitats being disconnected from the lower Fraser River floodplain (Birtwell et al. 1988). The majority of FRS covered in this RPA are lake-type ecotypes and rear within a nursery lake, and rapidly transit the lower Fraser during both outmigration to the ocean and during their return spawning migration. Thus, the impacts from reduced floodplain connectivity are likely minimal for these DUs compared to ocean-type FRS such as DU24 (Widgeon-RT), which are thought to rear in the lower Fraser for weeks to months before migrating out into the Strait of Georgia. These ocean-type FRS are likely the most impacted by reduced accessibility to off-channel and floodplain habitat. Flood control structures and their impacts on FRS are discussed in greater detail in section 4.1.7.2.

3.4. ELEMENT 7: EVALUATION OF THE CONCEPT OF RESIDENCE AND DESCRIPTION FOR SOCKEYE SALMON

SARA defines “residence” as “a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating” (DFO 2015b). Redds, i.e. spawning nests constructed by Pacific salmon and other fish species, are considered residences because they meet the following criteria:

1. individuals (not a population) make an investment (e.g., energy, time, defense) in the redd and/or invest in the protection of it;
2. the location and features of the redd contribute to the success of a life history function (i.e., breeding and rearing);
3. the redd is a central location within an individual's larger home range, with repeated returns by the species to complete a specific life function.

There is an aspect of uniqueness associated with the redd, such that if it were "damaged" the individuals would usually not be able to immediately move the completion of the life history function(s) to another place without resulting in a loss in fitness (DFO 2015b). Sockeye Salmon are semelparous and are therefore unable to replace a damaged redd following their death. The fertilized eggs are functionally immobile until the egg develops into an alevin. The eggs must remain buried deep in the gravel otherwise other predatory fishes, such as cottids, will eat them (Steen and Quinn 1999; Foote and Brown 1998).

4. THREATS AND LIMITING FACTORS TO THE SURVIVAL AND RECOVERY OF FRS

4.1. ELEMENT 8: THREATS TO SURVIVAL AND RECOVERY

This report follows the definition of threats found in the "Guidance on Assessing Threats" Science Advisory Report (DFO 2014a). A threat in the context of this RPA may be defined as any human activity or process that has caused, is causing, or may cause harm, death, or behavioural changes to FRS, or the destruction, degradation, and/or impairment of its habitat, to the extent that population-level effects occur. Limiting Factors are defined as natural (abiotic or biotic) factors that negatively affect the productivity of FRS populations. A human activity may exacerbate a natural process and be deemed a threat, which is important to consider in the context of Element 10, Limiting Factors.

The threat categories are based on the IUCN-CMP (World Conservation Union–Conservation Measures Partnership) unified threats classification system (Salafsky et al. 2008), which COSEWIC uses to assess the status of wildlife species. The threat classification system was originally developed to define broad categories of threats. The assessment of the threat categories follows DFO's (DFO 2014a) Guidance on Assessing Threats, Ecological Risk and Ecological Impacts for Species at Risk, to the extent possible in the context of limited data and information on threats to FRS within Canadian waters (DFO 2014a). A working group assessed threats to FRS DUs using the IUCN-CMP threat assessment method used by COSEWIC during a three day workshop (Appendix B). Each DU was treated individually by the group, and all threat categories were discussed with the assistance of a COSEWIC moderator to ensure threats were scored according to IUCN-CMP guidelines. For each individual threat category the room was surveyed for expert opinion, and following a group discussion a vote was made for threat rankings. No threats were scored without group consensus. The threat assessments determined during the workshop were subsequently converted to the DFO standardized assessment method (DFO 2014a).

The COSEWIC threats calculator generates an estimated overall threat risk with a low and a high value to express the uncertainty in the rankings at the individual threat level (i.e. when a range such as Low-Medium was used). The overall scores are based on the number of threats impacting a DU and their relative ratings (from low to extreme). Two medium level threats and a high threat result in a High overall score. Two high and two medium threats, or an extreme score on any threat, results in an Extreme overall score. The lower range value of the overall score for all the DUs under consideration was determined to be either High or Extreme, and the upper range of the overall score was estimated to be Extreme for 5 of 9 of the DUs assessed in the workshop. This resulted in High, High to Extreme, or simply Extreme ratings for all DUs. In some cases the final threat rank generated by the threats calculator was reduced or altered following advice from the COSEWIC moderator and a group vote (these changes are noted in threats calculators in Appendix B). The results from this process indicate that over the next three generations (2021-2032), it is expected that there will be a population level decline of 31-70% for DUs with a High risk level, 71-100% for DUs with a High to Extreme risk level, and a 71% to 100% population level decline for DUs with an Extreme risk level.

The following sections represent the rationale used to estimate Likelihoods of Occurrence, Levels of Impact, Causal Certainties, and Threat Occurrences, Frequencies, and Extents for the threats tables below. Detailed definitions of the levels of the aforementioned aspects can be found in DFO (DFO 2014a). The threat occurrence and frequency assigned to each threat in the tables below are not discussed explicitly in the following sections to avoid excessive repetition. For almost all threats, occurrence is historical, current and anticipatory, as every threat assessed has occurred, is occurring, and is expected to occur in the future. Threat frequency is either recurrent, for threats that are not expected to occur regularly, or continuous, for threats that are expected to occur frequently or have ongoing continuous impacts. Categories in the text are organized by the order in which they appear in the COSEWIC threats list and not by threat risk. The results of the workshop assessment for each threat category are summarized in tables below including the threat risk per DU, and are organized by threat risk. Complete threat tables for each individual DU that were assessed during the workshop are available in Appendix B. In some cases, a threat category was omitted if it was not deemed to be a threat to FRS. Any category omitted was identified at the top of the section.

Table 5. Definitions for the Levels of Impact, Likelihood of Occurrence, Causal Certainty, Threat Occurrence, Threat Frequency, and Threat Extent that may be assigned to each threat category. Definitions were modified from DFO (DFO 2014a) to include the clarification that the level of impact was evaluated based on the expected population level decline over a three-generation, or 10 year period (whichever is longer), if the threats are not successfully mitigated.

Level of Impact	Definition
Extreme	Severe population decline (e.g. 71-100%) over the next three generations or 10 year period (whichever is longer), with the potential for extirpation
High	Substantial loss of population (31-70%) over the next three generations or 10 year period (whichever is longer), or threat would jeopardize the survival or recovery of the population
Medium	Moderate loss of population (11-30%) over the next three generations or 10 year period (whichever is longer), or threat is likely to jeopardize the survival or recovery of the population
Low	Little change in population (1-10%) over the next three generations or 10 year period (whichever is longer), or threat is unlikely to jeopardize the survival or recovery of the population
Unknown	No prior knowledge, literature or data to guide the assessment of threat severity on population
Negligible	Negligible change in population (<1%) over the next three generations or 10 year period (whichever is longer), or threat is likely to negligibly jeopardize the survival or recovery of the population

Likelihood of Occurrence	Definition
Known or very likely to occur	This threat has been recorded to occur 91-100%

Likelihood of Occurrence	Definition
Likely to occur	There is 51-90% chance that this threat is or will be occurring
Unlikely	There is 11-50% chance that this threat is or will be occurring
Remote	There is 1-10% or less chance that this threat is or will be occurring
Unknown	There are no data or prior knowledge of this threat occurring

Causal Certainty	Definition
Very High	Very strong evidence that threat is occurring and the magnitude of the impact to the population can be quantified
High	Substantial evidence of a causal link between threat and population decline or jeopardy to survival or recovery
Medium	There is some evidence linking the threat to population decline or jeopardy to survival or recovery
Low	There is a theoretical link with limited evidence that threat is leading to a population decline or jeopardy to survival or recovery
Very Low	There is a plausible link with no evidence that the threat is leading to a population decline or jeopardy to survival or recovery

Threat Occurrence	Definition
Historical	Very strong evidence that threat is occurring and the magnitude of the impact to the population can be quantified
Current	Substantial evidence of a causal link between threat and population decline or jeopardy to survival or recovery
Anticipatory	There is some evidence linking the threat to population decline or jeopardy to survival or recovery

Threat Frequency	Definition
Single	Very strong evidence that threat is occurring and the magnitude of the impact to the population can be quantified
Recurrent	Substantial evidence of a causal link between threat and population decline or jeopardy to survival or recovery
Continuous	There is some evidence linking the threat to population decline or jeopardy to survival or recovery

Threat Extent	Definition
Extensive	71-100% of the population is affected by the threat.
Broad	31-70% of the population is affected by the threat.
Narrow	11-30% of the population is affected by the threat.
Restricted	1-10% of the population is affected by the threat.

4.1.1. Residential and commercial development

4.1.1.1. Housing and Urban Areas

The threat from housing and urban areas includes new footprints of human cities, towns, and settlements including non-housing development typically integrated with housing (IUCN-CMP threat category 1.1). Pollution from domestic and urban wastewater is discussed in section 4.1.9 (IUCN-CMP threat category 9.1).

The lower Fraser River has the highest density of residential and urban development in the Fraser River basin, and human populations in this area are expected to continue increasing at a low rate. Much of the lower Fraser River floodplain and delta has already been developed, and the increasing demands from rising human populations will likely lead to new development that may further encroach on FRS habitat. There will also be continued development in the middle and upper portions of the watershed upstream of the Fraser Canyon, yet given the reduced population densities in these areas, it is not thought that there will be significant impacts in the near future. All FRS must pass through the lower Fraser River twice in their lifetime: first as they outmigrate to the ocean, and again as they return to their spawning grounds. These fish are therefore likely to be exposed to new residential developments. However, due to their rapid migration through the lower Fraser, the footprint of these developments are not anticipated to constitute a significant threat to FRS.

In addition to in-river development, the majority of FRS assessed in this RPA are lake-type variants (all DUs except DU4 Widgeon-RT) and generally rear in a nursery lake for one or more years before outmigrating to the ocean. As a result most FRS can also potentially be exposed to the footprint of new lakeshore developments during the juvenile rearing stage, but the impacts from these developments are currently unquantified.

An unknown level of impact was chosen for all FRS DUs due to the lack of evidence to suggest a population-level decline from new residential and urban developments for both lake-type and ocean-type life-history variants. It should be noted, however, that while the impacts are unknown, they are not anticipated to be beneficial.

4.1.1.2. Commercial and Industrial Areas

The threat from commercial and industrial areas include new footprints of industrial activities and other commercial centers, including manufacturing plants, shopping centers, office parks, military bases, power plants, train and ship yards, and airports (IUCN-CMP threat category 1.2).

There are many industrial developments on the banks of the lower Fraser River, and the remaining habitat in this area is currently more prone to industrial development than residential or tourism development. Any new industrial developments along the river's edge are likely to be encountered by both outbound and inbound FRS, therefore this threat is considered to be extensive. However, as previously mentioned, FRS rapidly transit the lower Fraser during their migrations to and from the sea, therefore the footprint of new industrial developments is anticipated to pose a negligible threat to FRS. It is important to note that this threat category only considers the physical impacts from new industrial development; impacts that occurred from previous developments that encroach into the water are not considered in this assessment.

As mentioned above, the majority of FRS assessed in this RPA are lake-type variants (all DUs except DU4 Widgeon-RT) and could potentially be exposed to the footprint of new commercial/industrial development along lakeshore habitat within their nursery lakes. However, there is no evidence to suggest substantial development will occur within the next three generations (2021-2032) that will lead to impacts.

4.1.1.3. Tourism and Recreation

The threat from tourism and recreation includes new tourism and recreational sites with a substantial footprint (IUCN-CMP threat category 1.3).

The lower Fraser River has a high concentration of marinas, boat launches, and private docks that encroach into the water, and increasing urban densification in the Metro Vancouver may lead to increased pressure for further developments of these types. Overwater structures, such as marinas, reduce surrounding light levels, causing reduced growth and density of aquatic plants, and, in some cases, can eliminate seagrasses completely (Burdick and Short 1999; Shafer 1999). One study found that even some mitigation efforts, such as installing grating on the platforms, does not fully mitigate impacts from shading (Fresh et al. 2006). These structures, while small on their own tend to be aggregated in seagrass areas and could have cumulative impacts on habitat within these areas.

FRS transit the lower Fraser twice and may encounter these developments along their migratory corridor, therefore the threat is considered extensive for all DUs. As with other developments within this threat category, FRS are not anticipated to be at great risk from tourism development due to their limited residence time in the lower Fraser River, yet the impacts are currently unknown. There is also tourism development along the lakeshores of many FRS nursery lakes, with marinas, boat launches, docks, and other structures that may encroach into juvenile FRS habitat. However, as mentioned in section 3.1.2, approximately 70% of the freshwater residency period for FRS occurs offshore within the pelagic area of the lake (Gilhousen and Williams 1989), therefore the impacts are not anticipated to be high. DU24 (Widgeon-RT) may be at risk from future tourism developments following approval of the new Widgeon Marsh Regional Park Management Plan, which calls for increased public access and development of trails and day-use areas. The potential impacts of this planned development is currently unknown and may be negligible with proper mitigations.

Table 6. DFO threats assessment calculator results for impacts from Housing and Urban Areas for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Housing and Urban Areas

Designatable Unit (DU)	**Likelihood of Occurrence**	**Level of Impact**	**Causal Certainty**	**Threat Risk**	**Threat Occurrence**	**Threat Frequency**	**Threat Extent**
DU2 Bowron-ES	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU10 Harrison (U/S)-L	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU14 North Barriere-ES	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive

Table 7. DFO threats assessment calculator results for impacts from Commercial and Industrial Areas for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Commercial and Industrial Areas

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU2 Bowron-ES	Known	Negligible	Low	Negligible (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU10 Harrison (U/S)-L	Known	Negligible	Low	Negligible (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU14 North Barriere-ES	Known	Negligible	Low	Negligible (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Negligible	Low	Negligible (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	Negligible	Low	Negligible (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Negligible	Low	Negligible (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Negligible	Low	Negligible (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Negligible	Low	Negligible (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Negligible	Low	Negligible (4)	Historical/Current/ Anticipatory	Continuous	Extensive

Table 8. DFO threats assessment calculator results for impacts from Tourism and Recreation for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Tourism and Recreational Areas

Designatable Unit (DU)	**Likelihood of Occurrence**	**Level of Impact**	**Causal Certainty**	**Threat Risk**	**Threat Occurrence**	**Threat Frequency**	**Threat Extent**
DU2 Bowron-ES	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU10 Harrison (U/S)-L	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU14 North Barriere-ES	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive

4.1.2. Agriculture and aquaculture

IUCN-CMP threat category 2.2, Wood & Pulp Plantations was not included in this section because to our knowledge, there are no new wood or pulp developments that will encroach on any of the FRS DUs discussed in this report.

4.1.2.1. Annual and Perennial Non-Timber Crops

The threat from annual and perennial non-timber crops includes new footprints of farms, plantations, orchards, vineyards, mixed agroforestry systems (IUCN-CMP threat category 2.1). Threats resulting from the use of agrochemicals, rather than the direct conversion of land to agricultural use, are included under section 4.1.9.3 (IUCN-CMP threat category 9.3).

Much of the land base of the lower Fraser River has been converted to agriculture and much of the existing development is behind dikes, therefore the footprint of new agricultural development in FRS habitat is not anticipated to pose a major threat. The BC Ministry of Agriculture (2016) reported 67% (37,669 ha) of the Fraser Valley Regional District (Abbotsford, Chilliwack, Hope, Kent, Mission, Harrison Hot Springs) is actively farmed or supporting farming, with only 18% of land available for potential future development. Most of the remaining 18% (9,943 ha) is comprised of relatively small areas that provide limited opportunity for further agricultural development. The more likely threat to FRS is the intensification or conversion of existing agricultural land in the lower Fraser River area. In recent years, islands in the Fraser River near Chilliwack (e.g., Herrling Island) have been subject to clearing to allow for agricultural development, and there will likely be continued pressure for similar activities to meet rising demands in the Lower Mainland. This threat also includes construction of greenhouses on existing fields that can reduce stream areas through reductions in riparian area and changes to banks. From 2006 to 2016, the amount of land used for greenhouses in the Fraser Valley grew by 400,000 m^2 (Fraser Valley Regional District 2017), suggesting continued agricultural intensification is likely in the future.

All FRS DUs transit the lower Fraser River twice and portions of these populations are expected to encounter these developments during outmigration or return spawning migration, but likely has a low impact at the DU level due to the limited residence time in the area. Sockeye from DU24 (Widgeon-RT) are ocean-type variants and spend the longest time in the lower Fraser River, possibly delaying in side channels and sloughs, and this may increase their exposure (see section 3.1.3); however, the Fraser River below the confluence with the Pitt River is highly developed behind existing dikes and largely inaccessible, additional impacts may not be significant.

Beyond the lower Fraser River impacts, there are potential additional impacts from the footprint of agricultural developments within DU16 (Quesnel-S), particularly in the Horsefly area. This area has the highest concentration of agricultural activities in comparison to other DUs, with many small- to medium-sized farms and ranches that primarily produce beef cattle and hay (Holmes 2009). The level of impact from future agricultural development is currently unknown within the Horsefly River area therefore the score was not changed for DU16, but it could potentially be higher than the other DUs assessed.

4.1.2.2. Livestock Farming and Ranching

The threat from livestock, farming and ranching is defined as the direct impact from domestic terrestrial animals raised in one location on farmed or non-local resources, as well as domestic or semi-domesticated animals allowed to roam in the wild and supported by natural habitats (IUCN-CMP threat category 2.3).

Unmanaged cattle grazing can have deleterious effects on riparian and aquatic ecosystems (Charnley et al. 2018). Direct impacts include: trampling of spawning beds, destabilization of stream banks and alteration of channel morphology, compaction of upland soils (leading to increased runoff and biota), removal or heavy defoliation of key riparian plant species, and degradation of water quality (Platts 1981; Kauffman and Krueger 1984; Fleischner 1994; Belsky et al. 1999).

While it is possible for cattle to enter FRS habitat within some DUs, the impacts from this threat are thought to be negligible or non-existent for most DUs due to the location of cattle ranching operations, and the depth and location of spawning habitat for these DUs. The majority of DUs utilize spawning habitat that is either not within livestock grazing areas or is within medium-large streams at depths exceeding those transited by cattle. Livestock typically only enter low gradient sections of streams, and most may be deterred from entering or crossing streams by riparian buffers and fencing, which will limit the extent of their impacts. It should, however, be noted that despite regulations surrounding the use of fences to prevent cattle from entering streams, enforcement is difficult and often lacking.

The only DU anticipated to be threatened by livestock farming is DU16 (Quesnel-S), as cattle are often observed in river in the Horsefly River system where beef production makes up a large portion of agricultural activities. It is currently unknown what the impacts are at the DU-level from cattle trampling of spawning redds, but it is anticipated to be higher than the other DUs assessed, and is thought to pose a low-level threat to this DU.

4.1.2.3. Marine and Freshwater Aquaculture

The threats from marine and freshwater aquaculture include footprints of shrimp or fin fish aquaculture, fish-ponds, hatchery salmon, and artificial algal beds (IUCN-CMP threats category 2.4). This threat category also includes interactions between wild fish and hatchery fish allowed to roam in the wild. Threats from mixed stock fisheries are discussed in section 4.1.5.2, and threats from introduced genetics are discussed in section 4.1.8.

The majority of DUs covered in this RPA are lake-type populations with the exception of DU24 (Widgeon-RT), and largely migrate north into the Pacific Ocean via Johnstone Strait along the mainland coast, or along the east side Vancouver Island (see section 3.1.4). The physical footprint of net-pens is not anticipated to be a threat to FRS and is not ranked here, yet this area is a migratory corridor that contains a large concentration of salmon farms in the Discovery Islands area that potentially exposes ocean-bound juvenile FRS to a variety of pathogens and pollution associated with salmon farming operations. Threats regarding pathogens and disease from aquaculture are discussed in detail in section 4.1.8, and pollution generated from these activities is discussed in section 4.1.9.3.

The main threat to FRS within this category concerns interactions of wild FRS with hatchery-origin Pacific salmon. Between 1990 and 2015, hatchery salmon represented approximately 40% of the total salmon biomass in the Pacific Ocean, with Pink and Chum salmon making up the majority (87%) of overall adult abundance (67% and 20% respectively; Ruggerone and Irvine 2018). Increasing abundances of hatchery salmon across the North Pacific, and in particular hatchery Pink Salmon, have been linked to a trophic cascade in epipelagic waters leading to fewer zooplankton, and reduced growth and survival and delayed maturation of salmon (among other trophic effects; Springer and Van Vliet 2014; Ruggerone and Connors 2015; Batten et al. 2018; Connors et al. 2020). The abundance of adult Pink Salmon in the North Pacific alternates from high in odd-numbered years to relatively low numbers in even-numbered years, and a corresponding, inverse pattern has been observed in Sockeye Salmon productivity, length-at-age, and age at maturity (Ruggerone and Connors 2015). More recent studies have estimated that hatchery production of Pink Salmon reduced Sockeye productivity at the southern end of their range (which includes Fraser River stocks) by an average of 15% between 2005-2015 (Connors et al. 2020). There is further evidence that the effects from competition with Pink Salmon may be exacerbated when Sockeye Salmon are also exposed to hatchery salmon in the early marine period, and that there may be a compensatory interaction between coastal ocean temperature and farmed-salmon exposure (Connors et al. 2012). FRS may be at particular risk of competition with Pink Salmon because they share common prey at sea (Pearcy et al. 1988; Kaeriyama et al. 2000; Bugaev et al. 2001; Davis et al. 2005), and because FRS and Pink Salmon from distant regions are broadly distributed throughout the North Pacific Ocean, with a substantial degree of overlapping habitat with FRS (Myers et al. 2007; Beacham et al. 2014a; Ruggerone and Connors 2015). There is less overlap in diet and ocean distribution between FRS and Chum Salmon, and they also are considered to have different intrinsic strategies for survival (Azuma 1995; Davis et al. 2005). There is, however, evidence from stable isotope data that indicate high levels of overlap in resource use between Pink, Sockeye, and Chum salmon (Johnson and Schindler 2009), suggesting that continued increases in Chum Salmon abundance may lead to adverse competitive interactions with FRS. Despite these impacts, hatchery production of Pink and Chum salmon continues to increase in some jurisdictions (e.g., Alaska and Russia) with minimal consideration of adverse effects on distant salmon populations (Connors et al. 2020).

Hatchery fish produced in the Fraser River watershed also pose a potential threat to FRS, as some DUs are in direct competition with enhanced populations of Pacific salmon. For example, FRS that rear in Seton Lake from DU17 Seton-L compete with FRS produced in the spawning channel at Gates Creek, which are much more abundant (DU1 Anderson-Seton-ES; Not at Risk). FRS from DU10 Harrison (U/S)-L spawn almost exclusively in Weaver channel, and spawn timing overlaps with Chum and Pink salmon that also spawn in the channel. There are significantly higher numbers of FRS that spawn within the channel (target of 42,000) compared to Chum and Pink salmon (target of 2,500 each), and Pink Salmon are only present in odd-numbered years. Essington et al. (2000) showed reproductive success for FRS within the channel was strongly and inversely correlated with conspecific abundance, but not with the abundance of the less abundant Chum and Pink salmon. At current levels of channel production both intra- and interspecific competition are likely not a major threat to DU10, yet we highlight this as a potential threat if production were to increase under future management regimes.

All FRS DUs covered in this RPA are anticipated to be impacted similarly by competition with hatchery salmon in the North Pacific Ocean, due to the high, and increasing abundances of hatchery-origin Pink and Chum salmon from distant regions. A threat risk of Low-Medium was chosen; while there is evidence to suggest that FRS declines may exceed 10% as a result of hatchery competition, there is considerable uncertainty in these estimates at the DU-level, and it could not be ruled out that the impacts would be close to the lower range (10%). Subject matter experts were in agreement that the level of impact is unlikely to be at the high end of the range (30%).

Table 9. DFO threats assessment calculator results for impacts from Annual and Perennial Non-Timber Crops for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Annual and Perennial Non-Timber Crops

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU2 Bowron-ES	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Narrow
DU10 Harrison (U/S)-L	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Narrow
DU14 North Barriere-ES	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Narrow
DU16 Quesnel-S	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Narrow
DU17 Seton-L	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Narrow
DU20 Takla-Trem-EStu	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Narrow
DU21 Takla-Trem-S	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Narrow
DU22 Taseko-ES	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Narrow
DU24 Widgeon-RT	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Narrow

Table 10. DFO threats assessment calculator results for impacts from Livestock Farming and Ranching for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Livestock Farming and Ranching

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU16 Quesnel-S	Known	Low	Medium	Low (3)	Historical/Current/ Anticipatory	Continuous	Narrow
DU20 Takla-Trem-EStu	Known	Negligible	Medium	Negligible (3)	Historical/Current/ Anticipatory	Continuous	Negligible
DU21 Takla-Trem-S	Known	Negligible	Medium	Negligible (3)	Historical/Current/ Anticipatory	Continuous	Negligible
DU22 Taseko-ES	Known	Negligible	Medium	Negligible (3)	Historical/Current/ Anticipatory	Continuous	Negligible

Table 11. DFO threats assessment calculator results for impacts from Marine and Freshwater Aquaculture for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Marine and Freshwater Aquaculture

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU2 Bowron-ES	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU10 Harrison (U/S)-L	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU14 North Barriere-ES	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive

4.1.3. Energy production and mining

IUCN-CMP threat category 3.1 Oil & Gas Drilling and 3.3 Renewable Energy are not included in this section, as to our knowledge, these activities are not occurring directly within FRS habitat. Hydroelectric facilities are considered under section 4.1.7.2.

4.1.3.1. Mining and Quarrying

The threats from mining and quarrying include impacts due to the production of non-biological resources, specifically the exploration, developing, and producing of minerals and rocks (IUCN-CMP threat category 3.2). Impacts from chemical runoff from these activities is discussed in section 4.1.9.2 (IUCN-CMP threat category 9.2).

Mining and quarrying activities (placer mining, gravel extraction) occur throughout the Fraser River Basin, however these activities are not anticipated to occur directly in FRS spawning or rearing habitat. The physical impacts from these activities are therefore not expected to pose a significant threat to FRS (pollution from these activities is discussed in section 4.1.9).

DU16 (Quesnel-S) is the only FRS DU anticipated to be threatened by activities related to mining, due to recent events at the Mount Polley Mine. In August 2014, the largest tailings pond impoundment breach in Canadian history occurred at Mount Polley Mine, releasing approximately 25 million m^3 of copper and gold mine tailings material into Polley Lake, Hazeltine Creek, and Quesnel Lake (Klemish et al. 2019). The Mount Polley tailings dam was located upstream of Quesnel Lake, and the debris flow following the breach surged 9.2 km along the Hazeltine Creek channel and discharged into the west arm of Quesnel Lake, a semi-isolated, 113 m deep sub-basin connected to the main basin of the lake over a 35 m deep sill (Hamilton et al. 2020). An estimated 18.6 million m^3 of waste solids, liquids form the tailings pond, and scoured overburden from the creek channel was deposited into the west arm, which spread out as a subsurface plume increasing hypolimnetic temperatures, electrical conductivity, and turbidity (Petticrew et al. 2015; Mount Polley Mining Corporation [MPMC] 2016). The spill also resulted in a layer of waste up to 10 m thick in the deepest portion of the west arm (at depths below 100 m), and a surficial layer of waste over an area of at least 12 km^2 (Golder Associates 2017). Between the occurrence of the disaster and September 2018, an additional 10.8 million m^3 of effluent was estimated to have been released into the west arm (MPMC 2018), prolonging the impact on the Quesnel Lake ecosystem.

Investigations into the impacts of the disaster are ongoing, yet there is evidence of sediment transport and water quality issues, smothering effects, changes in food web dynamics, and biological/physiological responses in aquatic organisms, among others. (Klemish et al. 2019; Hamilton et al. 2020). During each spring and autumn since 2015, resuspension of particles from an unconsolidated layer of spill-related sediments at the lake bed has occurred, highlighting potential impacts from seasonally elevated turbidity on the ecology of the lake and the continued possibility for mobilization of sediment-associated contaminants throughout the Quesnel Lake ecosystem (Hamilton et al. 2020). A recurrent and visible “greening” has also become apparent within the lake since the autumn of 2014, which is clearly visible through satellite imagery (Hamilton et al. 2020). Following the 2014 breach, metal concentrations in water, sediment, and fish tissue samples (FRS and Rainbow Trout) from the west arm have been comparable to concentrations reported in studies that found evidence of metal toxicity effects including mortality, decreased growth, and chemosensory impairment in other fish species and aquatic biota (Klemish et al. 2019). Klemish et al. also reported a decline in the diversity of benthic invertebrate communities in the west arm following the breach (effects on plankton and other aquatic species are currently unknown; Klemish et al. 2019).

While there is a growing body of evidence the Mount Polley tailings breach is having a number of effects on the Quesnel Lake ecosystem, the population-level impacts on DU16 (Quesnel-S) are currently unknown. Future research is needed in order to quantify any population-level declines. Nonetheless, we acknowledge that these impacts will be negative overall and likely constitute a significant threat.

Table 12. DFO threats assessment calculator results for impacts from Mining and Quarrying for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Mining and Quarrying

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU16 Quesnel-S	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive

4.1.4. Transportation and service corridors

IUCN-CMP threat category 4.4 Flight Paths was not included in this section as to our knowledge, there are no airplane, helicopter, or drone flight paths that interfere with any FRS DUs.

4.1.4.1. Roads and Railroads

This threat category focuses specifically on the threat of road transportation and road construction (IUCN CMP threat category 4.1). Impacts from storm runoff are dealt with in section 4.1.9.1 (IUCN CMP threat category 9.1).

Road development is pervasive throughout the Fraser River basin, and all FRS DUs are anticipated to be exposed to new road development to some degree. For several DUs this exposure is expected to be minimal as they spawn either in protected areas (DU2 Bowron-ES), remote locations (DU20 Takla-Trembleur-EStu, DU21-Takla-Trembleur-S, DU22 Taseko-ES), or in areas unsuitable for new or further road development (DU10 Harrison-L, DU17 Seton-L). There is a higher concentration of roads in the areas surrounding DU14 (North Barriere-ES), DU16 (Quesnel-S), and DU24 (Widgeon-RT), therefore a larger proportion of these populations are likely exposed to road development. Railroads also run adjacent to, or cross streams within the DUs covered in this RPA. These include: the Fraser River, Thompson rivers (Lower, North, and South), Stuart River, and Portage Creek. To our knowledge, there is no proposal to expand or develop railways within the next three-generations, therefore it is unlikely to lead to any direct impacts in the near-future. It should be noted that this category does not include impacts associated with modifications to catchment surfaces from road and railroad development, or with pollution associated with road or railroads; refer to sections 4.1.7.3 and 4.1.9.2, respectively.

There is currently insufficient evidence to quantify the impacts on FRS from these activities. Conversely, upgrades to existing road networks may actually be beneficial when replacement structures such as bridges and culverts is included in the work. When culverts are not sized properly, they can become impassible to fish and cut-off large sections of upstream habitat (Mount et al. 2011); there is ongoing work throughout the Fraser River basin to replace old culverts with replacements built to higher standards.

4.1.4.2. Utility and Service Lines

This threat focuses specifically on the transport of energy and resources(IUCN CMP threat category 4.2). Impacts from oil spills from pipelines and groundwater contamination are dealt with in section 4.1.9.2 (IUCN CMP threat category 9.2).

There are three major pipelines adjacent to FRS habitat: the TransMountain Pipeline, the Westcoast Transmission System Pipeline, and the Coastal Gaslink Pipeline. The TransMountain Pipeline transports crude oil. It is the most extensive utility route near freshwater habitat used by FRS, and crosses approximately 1,000 fish-bearing streams between Edmonton and Burnaby (TransMountain 2018[6]). The TransMountain Pipeline runs through the upper Fraser River basin (upstream of DU2 Bowron-ES), along the length of North Thompson (migratory route for DU14 North Barriere-ES), along a sub-basin of the Lower Thompson (i.e., Coldwater River), and along the lower Fraser River floodplain. The Westcoast Transmission System Pipeline transports liquid natural gas. It parallels the upper Fraser River beginning at Prince George, is diverted away from the river near William's Lake, and then follows the Trans Mountain Pipeline route along the Coldwater and lower Fraser rivers. A major construction project is currently underway to twin the TransMountain Pipeline, which will double it's current

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[6] Trans Mountain Watercourse Crossings in Burnaby.

capacity. Efforts are being made to minimize impacts from stream crossings in the Thompson River watershed through horizontal directional drilling (North Thompson River, Blue River, Raft River, Clearwater River, and Mann Creek), and while there may be local impacts in these streams, it is unlikely there will be direct physical impacts on FRS habitat. The Westcoast Transmission line will also require upgrading in the future, as the polyethylene tape, previously used for patching, is now considered to be a hazard and has to be replaced. The Coastal Gaslink Pipeline is a 670 km liquid natural gas pipeline currently being constructed between Dawson Creek and Kitimat, and will cross the Stuart River where all fish from DU20 (Takla-Trembleur-EStu) and DU21 (Takla-Trembleur-S) must migrate through[7]. The physical impacts from construction and repairs to these pipelines should be minimal if appropriate mitigation measures are followed.

All FRS will be exposed to activities relating to maintaining and upgrading of the TransMountain and Westcoast pipelines to some degree within the next 10 years, given the proximity of these pipelines to various portions of FRS migration routes through the lower Fraser River and North Thompson River and its tributaries. DU14 (North Barriere-ES) is likely the most exposed to these activities as this population migrates through a portion of the North Thompson River as well as the lower Fraser. All FRS from DU20 and DU21 will migrate past the Coastal Gaslink Pipeline as it crosses the Stuart River. A free-spanning temporary bridge was recently constructed over the Stuart River for construction of the Coastal Gaslink Pipeline to minimize environmental impacts, however, in the event of a major event (structure failure, accident during construction, etc.) there could be significant in-river impacts that could affect these two DUs. Despite some DUs being potentially exposed to these activities, given proper mitigations this threat will likely have a negligible impact at the DU-level. Potential impacts from pollution in the event of a spill are discussed in section 4.1.9.2.

4.1.4.3. Shipping Lanes

This threat category includes impacts associated with transport on and in freshwater and ocean waterways (IUCN-CMP threat category 4.3) and includes dredging activities; the physical footprint from log booms and barges; and wake displacement.

Historically, the lower Fraser River possessed an extensively braided and highly active channel that wandered relatively unconstrained over a broad floodplain (Ham 2005). The channel has since been extensively modified over the last century to provide flood protection and adequate draft for navigation of ocean-going vessels (Nelson et al. 2017). Sediment removal by dredging below New Westminster (in combination with river training, bank hardening, and scour protection) has significantly altered channel hydraulics, sediment transport characteristics, and the morphology of the river (Nelson et al. 2017). Lowering of the river bed over time has also led to increased exposure of hard and less erodible materials that cause additional turbulence and plunging flows, amplifying the effects of channel modification and causing deep scouring (>20 m at some sites; Nelson et al. 2017).

Dredging activities are not anticipated to occur during critical times nor in the littoral zone of the river. However, all FRS DUs migrate through this corridor and are potentially exposed to dredging and shipping activities, therefore the threat is considered extensive. As most FRS transit the lower Fraser rapidly, both as juveniles on their way to the ocean and adults returning to spawn, the direct impacts from these activities are not expected to be significant, though the cumulative effects of alterations on the morphology and hydrology of the lower Fraser are currently unknown. The lower reach of Weaver Creek which is natal stream for DU10 (Harrison(U/S)-L), has also been dredged a number of times to maintain access to Weaver Creek Spawning Channel. The intended purpose of this dredging is to a maintain a migration

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[7] Coastal Gaslink Approved Coastal Gaslink Route.

corridor and holding pools for adult salmon in Weaver Creek when stream discharge is low (Grant et al. 2011), and this activity is not anticipated to be a threat to this DU.

The lower Fraser River is also an active log boom shipping channel, and contains a high concentration of log booms and barges. Storage of logs in the lower Fraser is common because brackish waters protect logs from wood borers and the storage areas are located in proximity to many processing mills (Sedell et al. 1991). The transport, storage and dumping of logs in aquatic habitats can lead to a variety of adverse physical, chemical, and biological effects to the surrounding environment (Power and Northcote 1991). Log booms can compact, scour, and shade nearshore habitats which in turn can reduce plant cover and food availability for juvenile salmon (Nelitz et al. 2012). A large proportion of tide-marsh habitat in the lower Fraser has been used as moorage for log booms and barges, and it is common for booms to become grounded potentially impacting critical habitat for juvenile fish and other aquatic species. Additionally, wood and bark debris can also accumulate beneath storage areas and alter the composition of food sources, smother emergent vegetation, increase biological oxygen demand, and increase concentrations of potentially toxic log leachates (Nelitz et al. 2012). Log booms can attract salmon seeking refuge, however they can also attract predators such as Killer Whales and Harbour Seals. The latter use log booms as haul-out sites and for pupping (Baird 2001; Brown et al. 2019). While these additional impacts from log booms beyond their physical footprint were not a contributor to the threat ranking, they may exacerbate the predatory effects discussed in section 4.1.8.2.

We note DU24 (Widgeon-RT) is potentially the most impacted by shipping and dredging activities due to their ocean-type juvenile life history, and assumed extended residence time in the lower Fraser following emergence (see section 3.1.3). There is currently little information about the distribution and habitat use of Widgeon Sockeye, owing to the considerable challenges in detecting individuals from such a small population within an area as large as the lower Fraser River and its estuary.

Table 13. DFO threats assessment calculator results for impacts from Roads and Railroads for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Roads and Railroads

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU2 Bowron-ES	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Negligible
DU10 Harrison (U/S)-L	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Restricted
DU14 North Barriere-ES	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Broad
DU16 Quesnel-S	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Broad
DU17 Seton-L	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Restricted
DU20 Takla-Trem-EStu	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Restricted
DU21 Takla-Trem-S	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Restricted
DU22 Taseko-ES	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Negligible
DU24 Widgeon-RT	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Narrow

Table 14. DFO threats assessment calculator results for impacts from Utility and Service Lines for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Utility and Service Lines

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU14 North Barriere-ES	Known	Negligible	Low	Negligible (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Negligible	Low	Negligible (4)	Anticipatory	Continuous	Restricted
DU20 Takla-Trem-EStu	Known	Negligible	Low	Negligible (4)	Anticipatory	Continuous	Restricted
DU21 Takla-Trem-S	Known	Negligible	Low	Negligible (4)	Anticipatory	Continuous	Restricted

Table 15. DFO threats assessment calculator results for impacts from Shipping Lanes for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Shipping Lanes

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU2 Bowron-ES	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU10 Harrison (U/S)-L	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU14 North Barriere-ES	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive

4.1.5. Biological resource use

IUCN-CMP threat categories 5.1 Hunting & Collecting Terrestrial Animals, and 5.2 Gathering Terrestrial Plants was not included in this section as these activities likely have no impact on FRS.

4.1.5.1. Logging and Wood Harvest

This threat category includes impacts associated with the direct physical activities of harvesting trees and other woody vegetation for timber, fibre, or fuel (IUCN-CMP threat category 5.3). Pollution as a result of these activities (e.g. sedimentation, fire retardant) is scored in section 4.1.9. Impacts from the reduction of forest cover (changes to runoff dynamics and stream hydrology, slope instability) is discussed in section 4.1.7.

Extensive timber harvest and associated activities have occurred throughout the Fraser River Basin. When riparian protection regulations are followed, the direct physical impacts in streams and lakes from logging activities should be minimized. However, in the BC Forest Planning and Practices Regulations (BC Reg 14/04), there is an exemption under section 51(1)(g) for the felling of trees in the riparian area if they have been damaged by fire, insects, or disease. Logging may therefore occur right to the water's edge when salvaging burnt or damaged timber. A massive mountain pine beetle outbreak and numerous catastrophic wildfires have prompted aggressive salvage logging operations to recover as much of this wood fibre as possible (BC Ministry of Forests 2004; BC Ministry of Forests and Range 2005; Schnorbus et al. 2010). In the event of salvage logging in riparian areas it is probable there will be some intrusion into FRS habitat, either by machines, felled trees or debris. Forest disturbances in the form of pests, diseases and wildfires are likely to increase in BC with climate change (Woods et al. 2010; Haughian et al. 2012), so unless forest regulations and practices change, future salvage logging in riparian areas can be expected.

Several DUs are not anticipated to be impacted by riparian logging activities due to the location of their spawning grounds (DU2 Bowron, DU10 Harrison (U/S)-L, DU17 Seton-L, DU22 Taseko-ES, DU24 Widgeon-RT), whereas forestry harvesting activities within watersheds occupied by DU14 (North Barriere-ES), DU16 (Quesnel-S), DU20 (Takla-Trembleur-EStu), and DU21 (Takla-Trembleur-S) are expected to pose a low level threat to a portion of the population. This threat does not include impacts associated with modifications to catchment surfaces from logging activities, or with pollution associated with forestry (refer to sections 4.1.7.3 and 4.1.9.3).

4.1.5.2. Fishing and Harvesting Aquatic Resources

This threat is defined as harvesting aquatic wild animals or plants for commercial, recreation, subsistence, research, or cultural purposes; and includes accidental mortality/bycatch (IUCN-CMP threat category 5.4).

Sockeye fisheries in Canada include: First Nations Food, Social, and Ceremonial (FSC) fisheries; recreational fisheries; commercial fisheries (including First Nations Economic Opportunity); and test fisheries. US fisheries on Fraser Sockeye are mainly by the commercial sector, with smaller fisheries by the recreational sector and for ceremonial and subsistence purposes. There are currently 24 Sockeye DUs in the Fraser River basin, yet in terms of abundance FRS are dominated by a few large and productive stocks (i.e. Chilko, Shuswap, Quesnel). A major concern in such mixed-stock fisheries is that more abundant stocks are co-harvested with weaker or smaller stocks that share similar migration timing, leading to potentially high impacts on already depressed stocks. There are examples of mixed-stock fisheries effects from previous management regimes that led to complete elimination of some Pacific salmon populations such as wild Coho Salmon in the lower Columbia River (Policansky and Magnuson 1998), various Chum Salmon populations in BC (Beacham et al. 1987), and declines of many other salmonid populations including FRS (Collie et al. 1990).

The main directed fisheries in Canada for FRS occur in Johnstone Strait, Juan de Fuca Strait, and the Fraser River, in addition to smaller fisheries along the West Coast of Vancouver Island. Directed US fisheries on FRS occurs in Juan de Fuca Strait, around the San Juan Islands, and north to the US-Canada border (US regulatory areas 4B, 5, 6C, 6, 7, 7A). The US share of FRS total allowable catch (TAC) for international sharing is 16.5%. There are no fisheries targeting FRS in Northern BC or Alaska, although by-catch of FRS in fisheries targeting other stocks and species does occur. These impacts are highly uncertain at the DU or even MU level as bycatch may go unreported and there is no associated stock identification with recorded bycatch. First Nations FSC are the highest FRS fishery priority within Canada once conservation needs are accounted for, followed by commercial and then recreational fisheries. First Nations FSC fisheries directed on FRS may occur anywhere along the FRS migration route in Southern BC, including marine areas on the inside and outside of Vancouver Island, and throughout the Fraser River and its tributaries (DFO, 1999). Gear types for these fisheries vary widely depending upon fishery location, and include the use of seine, gillnet and troll, and recreational hook and line gear. Within the river, gillnets and angling gear may be used, as well as gears such as shallow seine, beach seines, fish wheels and dip nets.

Commercial fisheries licenced by area and gear for FRS in BC are the Area B seine, Area D and E gillnet and Area G and H troll fleets (refer to commercial salmon licence area maps). Recent low abundances of Fraser Sockeye have limited commercial Sockeye fishing opportunities to the dominant Late Run year, which occurs on the 2018 cycle line. The last Canadian commercial fishery directed on Fraser Sockeye in a non-dominant year was a small Area B fishery in 2013. There are, however, non-targeted commercial fisheries that routinely intercept FRS such as Pink Salmon fisheries on odd-numbered years. Area B seine and Area H troll have shifted from a derby-style fishery to a transferable quota approach in response to reduced opportunities, and to support fisheries manageability and improved value. There are also First Nations in-river economic fisheries for FRS. DFO has acquired a number of regular commercial licences through buy-back programs and transferred the allocation associated with them to in-river First Nations. Generally, this results in replacing some of the mixed-stock ocean fishery effort with in-river commercial fisheries in specific semi-terminal and terminal areas. These fisheries use selective gear, location, and/or timing to minimize impacts on at-risk DUs.

Recreational fisheries are typically permitted if abundance is deemed to be sufficient. Specific time and area management measures may be implemented to protect imperilled DUs. Similar to commercial fisheries, directed recreational effort on FRS is now mostly limited to the 2018 cycle line. However, non-targeted fishing activities in, or near terminal areas may have impacts on FRS through incidental capture or disturbance of staging fish potentially resulting in mortality. Notable recreational fishing occurs near terminal areas within DU10 (Harrison River), DU14 (Barriere River), and DU16 (Horsefly River), yet the impacts of these activities are unknown and are not included in the threats assessment.

Unlike many other salmon fisheries in BC, in-season management of commercial fisheries directed on FRS in BC and Washington State waters occurs through a bilateral US-Canada Fraser River Panel (FRP) process which meets multiple times each week during the FRS return migration in July and August (occasionally into September). An abundance-based harvest control rule is identified pre-season for each MU. The TAC defined by the harvest control rule incorporates the expected in-river mortality associated with adverse migration conditions for the Early Stuart, Early Summer and Summer MUs and associated with early upstream migration timing for the Late MU. The in-season decisions made by the FRP are informed by test fishing, in-river passage estimates, stock ID from DNA, and estimates of run size, run timing, diversion rate and in-river mortality. Fisheries decisions typically occur at the MU scale, with escapement goals, allowable exploitation rates (ER), and TACs calculated for each of the four FRS MUs.

The following is the rationale used for scoring threats related to fishing and is based off data provided by the PSC and DFO Stock Assessment (see threats calculator Appendix B). Due to the presence of cyclic stocks in each MU, the ERs tend to follow a four-year pattern. There are sources of uncertainty that would result in ER estimates being biased low: the estimate of catch associated with illegal fishing activities; only some of fishing-related incidental mortality, both from fisheries directed on salmon or on other species (across all life history stages), are estimated. We note that illegal fishing activity catch could have a disproportionately greater impact on low abundance DUs, yet there is currently little information to quantify these effects. In addition, there are several factors that increase the uncertainty of ER estimates in general: uncertainties in estimation of catch, run size, and en-route mortalities; uncertainties on the release mortality rates used to calculate release mortality numbers, as current estimates are based on historical studies; and difficulties associated with assigning the proportion of catch and run size to small abundance stocks due to sample size. This last factor is particularly relevant to the Endangered or Threatened DUs covered in the RPA, as they often make up a small proportion of stocks migrating at any given time and location.

Early Stuart MU

DU20 (Takla-Trembleur-EStu) is protected by a window closure and harvest goals aim for less than 10% ER; however, there is concern that the actual mortality rates could be higher than estimated due to management uncertainty, illegal or unaccounted fishing activities, and bycatch mortality. There is a terminal First Nations fishery on DU20, yet the Nations have voluntarily ceased harvest following the Big Bar landslide.

Due to the disagreement about being less than 10% exploitation, the uncertainty range of 1-30 was chosen for severity with the acknowledgement that it is unlikely to be at the low end (1%), but also not likely to be as high as 30%. It was noted that with the recent Big Bar landslide and recently observed low abundances (see section 2.2.2), if productivity is below replacement over several generations removals could lead to more serious declines.

Early Summer MU

Harvest impacts on this MU is primarily driven within the MU by the later-timed, cyclic Early Thompson stocks (designated as Not At Risk by COSEWIC) and externally to the MU by allowable ERs on the Summer Run MU.

DU2 Bowron-ES: these fish are among earliest-timed migrants into the river, and while there are protections in place for Early Stuart that extends into the Bowron migration window, this DU is estimated to have experienced an average ER of 26% between 2009-2016. This DU co-migrates with early Shuswap Sockeye (DU19) FRS, which in dominant years has considerable fishing pressure from Canadian and US fisheries. There is great uncertainty associated with ER estimates due to the low abundance of this DU. Nonetheless, the group felt 11-30% was appropriate for level of impact, with the acknowledgement that this is more likely in the upper range of this value (30%).

DU22 Taseko-ES: this is a small stock that appears to migrate later than other Early Summer DUs, and as a result does not receive the same protection from early window closures. These fish are intercepted in fisheries targeting other more abundant Early Summer and Summer Sockeye stocks, particularly in the Chilko (DU3 and 4) and Shuswap (DU19) rivers, and on dominant years ERs are likely higher than 30%. The group felt fishing posed a medium-high level of threat (11-70%) for Taseko, with the acknowledgement that impacts are unlikely on the high end of this range.

DU14 North Barriere-ES: this DU is one of the later timed Early Summer components and its migration timing overlaps with the earlier timed Summer-run FRS stocks. Chilko is a key driver for harvest pressure, yet on years where fisheries are targeting late Shuswap fish there could be additional impacts. There is considerable uncertainty in the severity, and while the group agrees it could potentially higher than 30% it is unlikely to be at the high end of the range (70%).

Summer MU

Harvest impacts on this MU is primarily driven within the MU by Chilko and, every four years, externally to the MU by allowable ERs on the Late Run MU. Later timed components of the MU can be affected by fisheries on Pink salmon in odd-numbered years.

DU16 Quesnel-S: ERs vary considerably across years for this DU, yet between 2009-2016 these fish experienced an average ER of 38%. This DU is composed of two main groups from the Horsefly and Mitchell systems and fishing impacts are dependant on which group dominates the return. The Mitchell component returns later than Horsefly Sockeye, and these fish may be greater risk of being intercepted in fisheries targeting late-run Sockeye (e.g. Shuswap). Chilko (DU4 Chilko-S) is a key driver for harvest and could lead to greater fishing impacts on years with a large Chilko return. There is considerable uncertainty in the severity, and while the group agrees it could potentially higher than 30% it is unlikely to be at the high end of the range (70%).

DU21 Takla-Trembleur-S: ERs in 2018 and 2019 were estimated to be less than 10%, yet in years prior this ranged between 7-55%. ERs on this DU will typically be affected by fisheries directed on Summer Run (generally DU4 Chilko-S abundance), Late Run (generally DU18 Shuswap Complex-L), and Fraser Pink Salmon. The group agreed that 11-70% was appropriate for severity (high range of uncertainty) with the acknowledgement that future management regimes are likely to be more conservative and are unlikely to be at the high end of the range.

DU24 Widgeon-RT: this is the only ocean-type stock considered here, yet owing to its low abundance and unique life-history we have extremely limited information surrounding abundance and migration timing. This DU appears to have similar return timing to DU21 (Takla-Trembleur-S), therefore the group felt it should have similar fishing impacts (11-70%).

Late MU

Harvest impacts on this MU is primarily driven within the MU by the cyclic Late Shuswap and externally to the MU by allowable ERs on the Summer Run MU on non-dominant years and Fraser Pink salmon on odd years.

DU10 Harrison (U/S)-L: ERs estimated for DU10 are highly variable and affected by fisheries on more abundant co-migrating stocks (e.g., Late Shuswap) and species (e.g., Fraser Pink Salmon). The estimated ERs for DU10 are between 3% and 71% over the past 3 generations (M. Hague, PSC pers. Comm. 2021). The estimates of ER are considered particularly uncertain in years when DU10 makes up a small proportion of the total abundance of total Fraser Sockeye. Additional sources of uncertainty include unaccounted-for illegal fishing activity and management uncertainty. As such, the group felt it was appropriate to assign a rank a Medium-High (11-70%) with the acknowledgment that this is unlikely on the high end of this range.

DU17 Seton-L: FRS from DU17 will experience similar fishing-related impacts to other Late-run DUs. As such, the group felt it was appropriate to assign a rank a Medium-High (11-70%) with the acknowledgment that this is unlikely on the high end of this range.

Table 16. DFO threats assessment calculator results for impacts from Logging and Wood Harvest for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Logging and Wood Harvest

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU14 North Barriere-ES	Known	Unknown	Medium	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Narrow
DU16 Quesnel-S	Known	Unknown	Medium	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Narrow
DU20 Takla-Trem-EStu	Known	Unknown	Medium	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Narrow
DU21 Takla-Trem-S	Known	Unknown	Medium	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Narrow

Table 17. DFO threats assessment calculator results for impacts from Fishing and Harvesting Aquatic Resources for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Fishing and Harvesting Aquatic Resources

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU2 Bowron-ES	Known	Medium	High	Medium (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU10 Harrison (U/S)-L	Known	Medium-High	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU14 North Barriere-ES	Known	Medium-High	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Medium-High	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	Medium-High	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Low-Medium	High	Low-Medium (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Low-Medium	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Medium-High	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Medium-High	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive

4.1.6. Human intrusions and disturbance

IUCN-CMP threat category 6.2 War, Civil Unrest, & Military Exercises was not included in this section as these activities are not anticipated to impact FRS.

4.1.6.1. Recreational Activities

This threat category includes human activities that alter, destroy, or disturb habitats and species with non-consumptive uses of biological resources (IUCN-CMP threat category 6.1).

Recreational activities that may impact FRS include jet boat activity in or near spawning and/or rearing habitat, and ATV/UTV, dirt bike, or other form of transportation (e.g. horse) trampling redds or degrading habitat. FRS largely spawn and rear in areas inaccessible by terrestrial modes of transport (DU2 Bowron-ES, DU10 Harrison-L, DU14 North Barriere-ES, DU17 Seton-L, DU24 Widgeon-RT), yet there are areas within some DUs where activities (e.g. hunting, fishing, boating) may threaten a proportion of the population. This is particularly true in DU16 Quesnel-S, as many of the streams within the Horsefly system and McKinley areas are accessible by road, and jet boating is common in places such as the Mitchell River. It is expected a relatively large proportion of DU16 could be exposed to recreational activities, yet the impacts are likely low. These activities may also occur in the Stuart (DU20, DU21) and Taseko (DU22) drainages albeit to a lesser degree, and likely impact a much smaller proportion of the overall DU.

Jet boat use was identified as a threat to Fraser River Chinook Salmon that spawn in the upper reaches of the upper Pitt River (DFO 2020c), and while Widgeon Slough is in the lower portion of the Pitt River drainage, it is a high traffic area and there is the potential for impacts on DU24 Widgeon-RT if boats enter spawning habitat. The current impacts on this DU are unknown, but as identified in DFO (2020c) jet boats can suck up fish or eggs causing direct mortality if the boats are driven through gravel beds or littoral habitat during critical periods. Additionally, boat wakes may strand juveniles along shorelines or from shallow habitats. The pressure fluctuations created under a passing jet in shallow water is also capable of killing salmon eggs incubating in the stream-bed, with mortalities of up to 40% in controlled laboratory studies (Sutherland and Ogle 1975). Recreational propeller or jet wash can also play a significant role in re-suspending bottom sediments, which can lead to erosion, internal nutrient loading, or elevated levels of turbidity and heavy metals in the water column (Hill 2002). A study conducted by Dorava and Moore (1997) demonstrated streambank erosion in a popular boating area of the Kenai River, Alaska, was 75% greater when compared to areas where boating restrictions are in place. Reduced water clarity may also interfere with the use of shallow water habitat by fish, in addition to wildlife habitat along the water's edge (Laderoute and Bauer 2013). There has been a call for a jet boat ban on the Pitt River by local residents and First Nations in recent years[8][9][10], and remains to be a potential threat to salmon that spawn in the system.

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[8] Luymes 2017. News article for the *Vancouver Sun: "Joy-riding jet boaters destroying Pitt River salmon: fisherman"*.

[9] Johnston 2020. News article for CBC News: *"First Nations, fishing guide push for jet-boat ban on Pitt River to protect salmon"*.

[10] Strandberg 2020. News article for Tricity News: *"Joy riders 'threaten' salmon, call goes out to ban jet boats on upper Pitt River"*.

4.1.6.2. Work and Other Activities

This category includes threats from people spending time in or traveling in natural environments for reasons other than recreation or military activities (IUCN-CMP threat category 6.3). This includes scientific research, and activities associated with law enforcement, drug smugglers, and illegal immigration.

This threat pertains primarily to capture and handling stress while conducting scientific research. There are a variety of science activities that occur in FRS-bearing streams that lead to direct interactions with humans. Field programs are generally designed to mitigate the negative effects of stress and activities are conducted in their best interest, yet there is often stress and mortality associated with catching and handling fish. This is particularly true for the transport of fish via truck, helicopter, or other modes of artificial transport (i.e. Whoosh system). Stress or injury related to capture and handling can provide opportunities for infection or elicit an immune response, in addition to causing physiological disturbances such as osmoregulatory imbalance that can impair overall host health and resilience (Eliason et al. 2011; Cooke et al. 2013; Robinson et al. 2013).

Considerable work has been conducted in the mainstem Fraser River following the Big Bar landslide, and all DUs that spawn upstream of the landslide will encounter any work or research activities occurring at the landslide site. For DU2 Bowron-ES DU20 Takla-Trembleur-EStu, and DU22 Taseko-ES, there will likely be directed activities associated with Big Bar in the future (i.e. capture, tagging, trap and haul, natal stream brood collection), and due to the small populations sizes it is likely these activities will intercept an extensive proportion of the population. There are directed stock assessment programs for DU21 Takla-Trembleur-S and one out of four years there is a mark recapture on the Tachie river. It is likely an extensive portion of these fish are exposed with low-level impacts (1-10%). DU16 Quesnel-S is the most abundant stock considered in this RPA, and while there are directed stock assessment programs for this DU it is likely that a narrow portion (11-30%) of the population is exposed to these activities with low level impacts. A broad (31-70%) portion of FRS from DU10 Harrison (U/S)-L are expected to be intercepted during the Harrison mark-recapture program, but some will likely miss these activities due to slight mismatches in timing. It is also noted that mark-recapture programs for other species (e.g. Chinook, Chum salmon) may also intercept Sockeye from DU10 resulting in mortality, but the impacts are not anticipated to be significant with proper planning and mitigations in place.

Foot surveys are conducted within DU14 North Barriere-ES and DU24 Widgeon-RT, and due to small population sizes a large portion of the population are likely exposed; however, these activities are expected to have negligible effects at the DU-level. Activities within the Seton system also expose an extensive portion of DU17 to research activities that may lead to mortality (see section 4.1.7.2), and likely have a low-level of impact at the DU-level.

Table 18. DFO threats assessment calculator results for impacts from Recreational Activities for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Recreational Activities

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU16 Quesnel-S	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Broad
DU20 Takla-Trem-EStu	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Restricted
DU21 Takla-Trem-S	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Restricted
DU22 Taseko-ES	Known	Negligible	Low	Negligible (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive

Table 19. DFO threats assessment calculator results for impacts from Work and Other Activities for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Work and Other Activities

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU2 Bowron-ES	Known	Low	Medium	Low (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU10 Harrison (U/S)-L	Known	Low	Medium	Low (3)	Historical/Current/ Anticipatory	Continuous	Broad
DU14 North Barriere-ES	Known	Negligible	Medium	Negligible (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Low	Medium	Low (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	Low	Medium	Low (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Low	Medium	Low (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Low	Medium	Low (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Low	Medium	Low (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Negligible	Medium	Negligible (3)	Historical/Current/ Anticipatory	Continuous	Extensive

4.1.7. Natural systems modifications

4.1.7.1. Fire and Fire Suppression

This threat is defined as suppression or increase in fire frequency and/or intensity outside of its natural range of variation (IUCN-CMP threat category 7.1).

The frequency and intensity of forest fires is increasing as a result of climate change, historic forestry practices, pest infestations, pathogens, and incidences of human initiated fires (Mote et al. 2003; Wang et al. 2015). The increased prevalence of fire will in turn lead to more area burned, often with a higher severity, leading to further impacts on ecosystem function (Schoennagel et al. 2017). It should be noted fire-related ecosystems modifications are not considered in this category and are discussed further in Other Ecosystem Modifications. The immediate and direct heating from flames, and the lasting effect (removal of riparian stream cover) of a forest fire is increased stream temperatures that can affect the behaviour and physiology of juvenile salmon (Beakes et al. 2014). In addition, equipment conducting this work may inadvertently destroy habitat or release suspended sediments into the water column, indirectly impacting fish downstream.

Forest fires are not expected to occur on an annual basis, yet it is likely many DUs will be impacted by fire within the next three generations, or 10 year period in the case of DU24 Widgeon-RT. FRS largely spawn in areas that are relatively buffered from the effects of direct heating, therefore the direct impacts are expected to be low. Aerial bucketing is unlikely to impact FRS with the exception of extremely rare cases. Extensive burning of the riparian zone within some DUs could have direct local impacts, particularly within shallow systems, however the overall proportion of the DU would likely be restricted.

4.1.7.2. Dams and Water Management

This threat is defined as dams and water management/use activities which change water flow patterns from their natural range of variation either deliberately or as a result of other activities (IUCN-CMP threat category 7.2). This includes changes to water flow patterns and volumes (hydrology), sediment transport, and the in-river footprints of structures.

There are no major hydroelectric developments on the mainstem Fraser River that impact FRS, and the Fish Protection Act prevents the construction of new bank-to-bank dams on the Fraser in the future (COSEWIC 2017a). There are, however, major facilities on the Seton and Nechako rivers that impact FRS from DU17 Seton-L and DU20/21 Takla-Trembleur-EStu/S, respectively.

All FRS from DU17 (Seton-L) are exposed to hydroelectric development in the Bridge and Seton rivers (referred to as the Bridge-Seton hydroelectric complex). All fish returning to spawn in the Seton watershed must negotiate the Seton Dam tailrace, and locate and ascend a vertical-slot fishway (32 pools, two turning basins, 107-m-long, 6·9% grade, discharge: 1·0–1·3 m^3s^{-1}; Burnett et al. 2014) to reach spawning grounds in Portage Creek. Even successful passage through a fishway can have deleterious effects on fish that can negatively affect fitness or lead to delayed mortality (Roscoe et al. 2010), and there is considerable evidence that passage through the Seton Dam fishway has negative impacts on FRS in the Seton system. Previous work by Pon et al. (2006) and Roscoe et al. (2010) reported FRS passage efficiency of approximately 80%, yet stated this could be potentially lower due to difficulties locating the fishway and cumulative effects of stressors during migration (discussed further in next section). Burnett et al. (2014) indicated that Sockeye appeared to have less difficulty passing the fishway than they did locating and entering it, and these challenges were associated with the spilling of excess water through the dam's radial gate (Bett et al. 2020). Sockeye experience higher velocities near the Seton Dam fishway entrance that has been shown to lead to increased anaerobic recruitment that appears to have greater impacts on females compared to males, resulting in lower passage success (Burnett et al. 2014). Sockeye are also impacted by shut downs of the generating station that lead to increased water temperatures behind the Seton Dam, exposing fish to supraoptimal temperatures that influences their ability to locate, enter and pass the fishway. Further to impacts on migrating adult FRS, there is evidence indicating negative impacts on FRS during outmigration through Seton Dam into the Fraser River. Mortality can occur by smolt entrainment into the power canal and subsequent passage through the turbine of the Seton Generating Station, in addition to mortality while crossing the Seton Dam fish ladder, fish water release gate, or siphons (Faulkner et al. 2019). To estimate entrainment mortality of Sockeye smolts during outmigration, a yearly monitoring program estimates the timing of smolt outmigration and the proportion of smolts entrained in the Seton power canal (Faulkner et al. 2019). Between 2008 and 2018, smolt mortality estimates ranged from 0 to 14%, however, in 2014 and 2017, the Seton Generating Station was shut down during migration so mortality was 0%, and no estimates were completed in 2016 due to high discharges (Faulkner et al. 2019). It is noted that much of the research presented in this section has been conducted on Gates Creek Sockeye (DU1 Anderson-Seton-ES), which have earlier migration timing and consequently experience differences in temperatures and flows than FRS from DU17. Nonetheless, Sockeye from DU17 are anticipated to experience similar effects when transiting the Seton Dam fishway, and passage is expected to pose a similar level of threat.

FRS returning to the Seton River are faced with confusing directional cues en route to spawning grounds (Bett et al. 2020). Pacific salmon are guided to spawning grounds primarily by the odour of their natal streams and lakes (Hasler and Scholz 1983; Bett and Hinch 2016), and these attractive odours are present in water discharged through the generating station on the mainstem Fraser, approximately 1 km downstream from the confluence with Seton River (Bett et al. 2020). The water at the generating station is impassable to fish and attracts migrating FRS as there are higher concentrations of natal water than the mouth of the Seton River due to dilution from Cayoosh Creek (Bett et al. 2020). This was first identified as a threat by Andrew and Geen (1958), and following further research by Fretwell (1989) that demonstrated some salmon returned to the generating station tailrace after having migrated upstream to the Seton-Fraser confluence, diversion structures were constructed on Cayoosh Creek (current facility is known as Walden North) to minimize dilution of natal water in the Seton (dilution set at 20%; Bett et al. 2020). BC Hydro currently operates the system with measures in place to maintain these natal water dilution targets, though large fluctuations still occur (Middleton et al. 2018).

Recent studies have demonstrated notable effects on FRS when encountering natal water at the generating station powerhouse, and in response to alterations of flows from Cayoosh Creek resulting in different levels of natal water discharge at the mouth of the Seton River. FRS from Gates Creek (DU1 Anderson-Seton-ES, not covered in this RPA) showed a preference for undiluted natal water when compared with water diluted by 30% or more (Bett et al. 2018), and these levels were associated with 80% reduced odds of salmon entering the Seton River (Drenner et al. 2018). Further to this, for salmon that did enter the river migration times were longer, particularly for females (Bett et al. 2020). These results are consistent with previous research by Burnett et al. (2014) which demonstrated lower passage success, attraction efficiency, and increased migration time on FRS when exposed to higher dilution levels at Seton Dam, with females exhibiting significantly lower success when compared to males. Middleton et al. (2018) reported Sockeye slowed migration at the outlet to the generating station where undiluted natal waters enter the Fraser River, and a portion of fish (17%) made back-and-forth movements between receivers located at the generating station and the mouth of the Seton River suggesting some level of confusion when encountering directional cues at both locations. Environmental monitoring paired with these studies confirmed that these behaviours are not temperature-driven and are likely due to differential olfactory properties of the Seton River and Cayoosh Creek (Bett et al. 2020).

Beyond the direct impacts from difficulties locating and navigating the Seton Dam fishway, recent studies have shown carry-over effects on FRS from stressors encountered during upstream migration and during passage of the dam. FRS rely solely on endogenous energy reserves when migrating to spawning grounds, therefore expenditures of energy and accumulation of stress during migration (suboptimal temperatures, high flows, physical injury, predator avoidance, etc.) can be important to migration success (Bett et al. 2020). For example, Sockeye returning to Gates Creek exhibiting gillnet wounds (21–29% of females and 13–22% of males between 2014-2016) had a 16% lower probability of surviving to reach spawning grounds, and females with gillnet injuries had an 18% lower probability of releasing their eggs (Bass et al. 2018; Bett et al. 2020). Minke-Martin et al. (2018) reported fish exposed to high levels of discharge at the dam exhibited reduced reproductive longevity and a lower probability of females releasing their eggs on spawning grounds.

Hydroelectric development is anticipated to have a medium-level impact to FRS from DU17 (31-70%). In addition to the physical challenges with both locating and ascending the fishway at Seton Dam, there is evidence to suggest that negative stressors experienced during migration are amplified during dam passage and can lead to mortality or reduced reproductive success.

All FRS from DU20 (Takla-Trembleur-EStu) and DU21 (Takla-Trembleur-S) must enter the lower reaches of the Nechako River during their return spawning migration to the Stuart drainage and are thus exposed to heavily modified flows resulting from operations of Kenney Dam. Stuart Sockeye spend 3-4 days migrating up the lower Nechako River before entering the Stuart River, where they experience the warmest water temperatures (can exceed 22°C) during their normal 4-year lifecycle (Macdonald et al. 2007, 2012). Temperatures exceeding 20°C can lead to a variety of negative effects in salmon including: impediments to migration; reduced swimming performance from depleted energy resources; immunosuppression effects, disease development, and parasitic infection; and direct mortality (Macdonald et al. 2012; see section 4.1.11.3 for discussion on temperature effects). To mitigate these temperature effects, the Summer Temperature Management Program was initiated in 1981 in the Nechako to suppress stream temperatures below 20°C from July 20 to August 20, through controlled releases from Skins Lake Spillway for the benefit of migrating salmon (Islam et al. 2019a). Independent reviews have shown that this program has minimized occurrences of water temperatures higher than 20°C target for most years, and instances of exceeding this threshold are infrequent suggesting the program has been overall effective in mitigating temperature effects (Macdonald et al. 2012; Nechako Fisheries Conservation Program [NFCP] 2016; Islam et al. 2019a). There is, however, an increasing trend in air and water temperatures across parts of the Nechako and Upper Fraser watersheds, suggesting that temperature-related mortality of FRS will remain an ongoing concern for DU20 and DU21.

Due to mitigations in place at the Kenney Dam it is unlikely dam operations will lead to more than a low-level impact (1-10%) on DU20 and DU21, provided temperature thresholds (20 °C) are not exceeded during FRS migration. In the event of inadequate releases of water to cool stream temperatures in the lower Nechako, mortality could be potentially much higher than 10% as a direct result of dam operations. It is noted that due to warming trends in the Nechako region this threat may become a more of a problem in the future.

Water extraction for industrial, commercial, domestic and agricultural uses can reduce access to Sockeye spawning, rearing and migratory habitats, and reduce habitat quality (Marmorek et al. 2011). The majority of FRS DUs covered in this RPA migrate through, and spawn in areas with sufficient depth and flow that water extraction does not pose a major threat; however, FRS from

DU14 North Barriere-ES, and particularly DU16 Quesnel-S, migrate through areas where water extraction is high. Due to buffering effect from the Barriere lakes it is unlikely that water extraction poses more than a negligible threat to FRS from DU14. FRS from DU16 migrate through a heavily prescribed area for water use, particularly for the Horsefly component of the run, which can make up greater than 50% of the total return. A declining trend in summer water discharge in the Horsefly has been observed between 1964 – 2015, and low flow impacts may become more prevalent in the future with climatic shifts in the watershed (Shrestha et al. 2012; Stiff et al. 2018; see section 4.1.11.1). FRS returning to the Horsefly River experience low flows and the warmest temperatures during their migration in the lower reaches of the system (> 22 °C), and these conditions have been associated with bacterial infection, pre-spawn mortality, and reduced reproductive success within the Horsefly system (Macdonald et al. 2000; see section 4.1.11.3). A dam at the outlet of McKinley Lake was constructed in 1969 in an attempt to mitigate temperature effects on Horsefly Sockeye, with a siphon system to deliver cooler water from the lake hypolimnion to Horsefly spawning grounds via McKinley Creek, yet studies have indicated that the temperature-moderating capacity of the dam is largely restricted to McKinley Creek and undetectable in the lower Horsefly River (Macdonald et al. 2000; Grant et al. 2011; Stiff et al. 2018). The high prevalence of water extraction in the Horsefly watershed is anticipated to contribute to the frequency and intensity of low flow events, and likely poses a low level of impact to the overall DU16. However, the level of impact has the potential to increase in the future.

Water management poses a threat to FRS returning to DU10 Harrison (U/S)-L, as Weaver Creek has insufficient flows to supply both the spawning channel and maintain downstream flows. There are multiple water sources to supply the spawning channel (Ackerman et al. 2007). There is a small intake dam located on Sakwi Creek which is used when necessary to divert flow into the Weaver intake. There is also a gravity fed pipe siphon from the outlet of Weaver Lake that transports water approximately 200 m downstream of the lake outlet. When low water conditions in Weaver Creek do not permit sufficient channel input, the Sakwi diversion is activated, and if these two sources do not maintain sufficient flows, the Weaver Lake siphon is activated. A variety of impacts related to water management have been observed since the spawning channel was put into operation in 1965, including: flooding, sedimentation issues, physical blockages (e.g. logs, woody debris), algae blooms, disease, frazil ice formation, poor water quality (low dissolved oxygen), entrainment of air in water pipelines, poor migratory conditions, nutrient loading from organic material, and difficulties with Sockeye entering the channel (Rosberg et al. 1986). Improvements in infrastructure and water management have led to the resolution of some of these issues, including a well water supply to provide protection against freezing during winter outflow wind events, and installation of re-aeration plates to maintain appropriate dissolved oxygen levels and water quality (additional mitigations at Weaver Channel discussed in section 6.1.9). The impacts of water management at the DU-level is currently unknown for DU10 and was not ranked in the threats assessment, yet we note that without sufficient water management the impacts could be significant.

There has been significant modification or removal of historical riparian habitat in the lower Fraser River due to dikes and other structures for flood control (i.e. flood boxes, tide gates, etc.). There are approximately 600 km of dikes, 400 flood boxes and 100 pump stations in the Fraser River Basin (Fraser Basin Council 2019[11]). Due to their life history (rear in lakes, rapidly migrate to ocean), FRS are not as threatened as other salmonids that rely on seasonally inundated habitat for rearing (Chinook, Coho, Steelhead); however, these structures can still lead to alterations in behaviour and disrupt migration pathways.

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[11] Fraser Basin Council. 2019. Flood and the Fraser.

4.1.7.3. Other Ecosystem Modifications

This threat includes other actions that convert or degrade habitat in service of "managing" natural systems to improve human welfare. This includes land reclamation projects, abandonment of managed lands, riprap along shoreline, mowing grass, tree thinning in parks, beach construction, removal of snags from streams, effects on the hydrological regime from forestry and mountain pine beetle, changes in food web composition (IUCN-CMP threat category 7.3)

All FRS considered in this RPA are impacted by ecosystem modification, particularly DUs that spawn in the upper reaches of the watershed. Historical development, resource extraction, wildfires, and pest infestations have significantly altered the Fraser River watershed, with widespread modifications to catchment surfaces and increases in impervious surfaces that have altered flow dynamics and temperature regimes. Much of the information presented in this section has been summarized in previous salmon RPAs (interior Fraser Coho, Fraser Chinook), and is highly relevant for all anadromous Pacific salmon.

Forestry

Forest harvesting and management on crown land, as well as private land, is a major industrial activity throughout many FRS DUs, and can impact flow and temperature regimes in a variety of ways. Forestry activities have been prevalent in the Central Interior, the Cariboo – Chilcotin and the Omineca regions, impacting all the DUs treated in this RPA to some extent. Extensive forest harvesting (e.g. clear-cut logging) within a watershed may lead to stream channel instability, riparian habitat degradation, increased summer stream temperatures, and altered seasonal hydrographs by altering run-off dynamics (Meehan 1991). Historically, forest harvesting was associated with extensive removal of riparian vegetation, and the negative effects of these removals on stream temperature and morphology are well documented (Beschta et al. 1987; Poole and Berman 2001; Richter and Kolmes 2005; Quigley and Hinch 2006; Tschaplinski and Pike 2017a). Modern forest management practices attempt to reduce the impacts of harvesting on stream temperatures by leaving strips of riparian vegetation (buffers) intact (Beschta et al. 1987; Cole and Newton 2013; Bladon et al. 2018), yet there are lingering effects from past activities that contribute to ongoing flow and temperature issues experienced by FRS throughout the Fraser watershed. As mentioned in section 4.1.5.1, there is an exemption under section 51(1)(g) for the felling of trees in the riparian area if they have been damaged by fire, insects, or disease. Pine beetle infestations and forest fires that have occurred in large areas of the middle and upper Fraser River watershed recently, thus salvage logging based on current forest regulations and practices represents a considerable threat to stream habitat within impacted areas. The FRS DUs covered in the RPA do not spawn within areas that have been impacted by wildfires or disease and will likely not be directly impacted from salvage logging operations in the next three generations (or 10 year period for DU24 Widgeon-RT). However, unless regulations and practices governing salvage logging change, future salvage operations could contribute to further indirect negative effects on ecosystem function through modified hydrologic function. Sedimentation impacts associated with the construction of forest service roads is discussed in section 4.1.9.3.

Wildfires

Forest fires are becoming more frequent as a result of climate change, historic forestry practices, pest infestations, and incidences of human initiated fires (Mote et al. 2003; Wang et al. 2015). Historic wildfires in 2017 and 2018 led to the loss of over 3 million hectares of forest cover across the Province of BC, notably in the Cariboo-Chilcotin and the Central Interior regions. The impacts of forest fires are similar to forest harvesting in how they alter flow and temperature regimes, but there can be additional impacts as well. Wildfires do not follow forestry management rules and can remove all vegetation, including riparian. As noted in Fire & Fire Suppression, removal of forest by fire can increase irradiation levels from the sun that increase stream temperatures until vegetation regrows (Beakes et al. 2014). The loss of vegetation also causes changes to the natural hydrological cycle by increasing the rate of snowmelt, increasing the amplitude of minimum and maximum discharge, and modifying evapotranspiration dynamics (Springer et al. 2015). As well, severe fires have the potential to create hydrophobic soils by burning all organic content (Letey 2001). A greater prevalence of hydrophobic soils may increase the frequency and magnitude of bank erosion from high volume run-off events. Recolonization rates by plants may also be reduced from severe burns, which prolongs the impacts of the modified catchment. The widespread, intense fire activity in 2017 and 2018 has led to large areas with denuded vegetation and hydrophobic soils that are prone to severe erosion. This will likely continue to impact many basins within the Fraser and Thompson watersheds in years to come.

Urban and Industrial Development

Urban and industrial development increases the amount of impervious surfaces which can have a number of impacts on salmon. Impervious or semi-pervious surfaces include (but are not limited to) roads, structures with roofs, drainage and sewer systems, and turf and gravel recreational fields. Impervious surfaces alter stream dynamics by increasing the magnitude of peak and low flows due to the reduction of gradual penetration of water into the ground (Booth et al. 2002), which can result in bedload movements that destroy redds, strand fish, and change migration and foraging behaviours. Roads, particularly highways and gravel forestry roads, may also intercept shallow groundwater flow paths and amplify run-off effects at stream crossings (Trombulak and Frissell 2000). These effects are particularly evident in smaller stream at forestry road crossings. There are many government agencies involved in planning urban and industrial development, yet this type of activity is not directly under the control of any single government body. A lack of integrated planning for urban, rural, and industrial developments can lead to cumulative alterations in stream hydrology with greater peaks or decreased low flows and produce degraded water quality from urban storm-water runoff. The increase in impervious surfaces can also influence the amount of pollution entering streams (see section 4.1.9.1).

Ranking

Ecosystem modifications are a significant threat to FRS, and impact all fish from all DUs. Widespread modifications to catchment surfaces through removal of forest cover (forest harvesting, fires, pest infestations, etc.), channelization of streams (particularly the lower Fraser), adjacent development (from all sectors), and many other activities have had cumulative impacts on the hydrologic function and temperature within the Fraser River basin, which is further exacerbated by climate change (see section 4.1.11.1). The earliest timed DUs (DU2 Bowron-ES, DU20 Takla-Trembleur-EStu, DU22 Taseko-ES) are expected to be most impacted by ecosystems modifications, due to their greater reliance on, and sensitivity to temperature and discharge levels during spring freshet. DU20 is likely the most sensitive to the hydrologic regime of the Fraser River; even prior to the Big Bar landslide, high levels of mortality among upstream migrating adults related to high temperatures and/or flows have been observed. Due to the considerable uncertainty in estimates of direct mortality, and variable hydrological conditions from year to year, a medium-high level of impact (11-70%) was assigned for this DU, with the acknowledgement this is unlikely on the high end of the range (70%) every year (i.e. in some years conditions will be better). The other early-timed DUs, DU2 Bowron-ES and DU22 Taseko-ES, can also experience upstream migration impacts from high temperatures and flows in the Fraser River mainstem, as well as in the Bowron and Chilcotin (high flows only) rivers, respectively. These two DUs are also anticipated to experience a medium-high level of impact

(11-70%) from ecosystems modifications, yet, as with DU20, it is noted there will be years where conditions are more favourable, and mortality of less than 30% is likely.

Summer- and late-run FRS, particularly those that spawn above Big Bar (i.e., DU16 Quesnel-S, DU21 Takla-Trembleur-S), are still subject to flow and temperature impacts in the mainstem Fraser that lead to mortality, albeit to a lesser degree than the earlier-timed DUs. It was felt these DUs were not subject to the potentially high levels of impact experienced by their earlier counterparts (i.e., >30%); however, it is noted these populations are more likely to experience potential temperature effects within their natal spawning tributaries, resulting from ecosystems modifications. This is particularly true for the portion of DU16 that spawn in the Horsefly River, which lies in a landscape that has been altered for agricultural operations and forestry. FRS from DU21 Takla-Trembleur-S also migrate through areas modified for agriculture and are exposed to low flows and warm water conditions in the lower Nechako River during upstream migration to the Stuart drainage. Mitigation measures are in place at the dam to reduce summer water temperatures; however, there are occurrences where thresholds are exceeded, and with warming conditions overall in the Fraser River basin with climate change, this will likely become a greater threat in the future. FRS from DU17 Seton-L spawn within a highly modified ecosystem in Seton Portage (impacts from Seton Dam discussed in section 4.1.7.2) and are also subject to mainstem Fraser River flow impacts that can lead to mortality. DU14 North Barriere-ES is the only DU covered in the RPA that spawns in the North Thompson River watershed, which has experienced high levels of deforestation from harvesting, fires, and pest infestations. The spawning area within this DU is relatively intact at present, yet the discharge- and temperature-related impacts along the migration route in the Fraser) and lower Thompson rivers, are expected to be significant. These DUs (DU14, DU16, DU17, DU21) are anticipated to have moderate level-impacts (11-30%) from the cumulative impacts resulting from ecosystem modifications.

FRS from DU10 Harrison (U/S)-L spawn in a modified habitat in Weaver Creek consisting of a artificial spawning channel; however, the channel was created to benefit the DU by improving the quantity and quality of the spawning habitat and providing flood protection. DU24 Widgeon-RT is expected to be the least threatened from ecosystem modifications, as its Sockeye have the shortest migration distance and are under the strongest tidal influence due to proximity to the estuary. However, these fish migrate through and spawn in a modified environment, and mainstem hydrology issues in the Upper Pitt watershed could lead to negative impacts. As ocean-type Sockeye, Widgeon-RT smolts also have a longer residence time in the lower Fraser before migration to the ocean, and historic development has likely cut off significant portions of rearing habitat previously used by this DU. For both these lower Fraser DUs it was felt there is the potential for DU-level impacts greater than 10% from the collective modifications to the lower Fraser ecosystem, yet it is noted that it is unlikely these impacts will be near the high end of this range on an annual basis.

Table 20. DFO threats assessment calculator results for impacts from Fire and Fire Suppression for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Fire and Fire Suppression

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU2 Bowron-ES	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Restricted
DU14 North Barriere-ES	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Restricted
DU16 Quesnel-S	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Restricted
DU20 Takla-Trem-EStu	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Restricted
DU21 Takla-Trem-S	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Restricted
DU22 Taseko-ES	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Restricted

Table 21. DFO threats assessment calculator results for impacts from Dams and Water Management for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Dams and Water Management

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU10 Harrison (U/S)-L	Known	Unknown	Medium	Unknown (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU14 North Barriere-ES	Known	Negligible	Medium	Negligible (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Low	Medium	Low (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	Medium	Medium	Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Low	Medium	Low (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Low	Medium	Low (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Negligible	Medium	Unknown (3)	Historical/Current/ Anticipatory	Continuous	Extensive

Table 22. DFO threats assessment calculator results for impacts from Other Ecosystems Modifications for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Other Ecosystems Modifications

Designatable Unit (DU)	**Likelihood of Occurrence**	**Level of Impact**	**Causal Certainty**	**Threat Risk**	**Threat Occurrence**	**Threat Frequency**	**Threat Extent**
DU2 Bowron-ES	Known	Medium-High	Medium	Medium-High (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU10 Harrison (U/S)-L	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU14 North Barriere-ES	Known	Medium	Medium	Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Medium	Medium	Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	Medium	Medium	Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Medium-High	Medium	Medium-High (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Medium	Medium	Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Medium-High	Medium	Medium-High (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive

4.1.8. Invasive and other problematic species and genes

4.1.8.1. Invasive Non-Native/Alien Species

This threat is defined as harmful plants, animals, pathogens and other microbes not originally found within the ecosystem(s) in question and directly or indirectly introduced and spread into it by human activities (IUCN-CMP threat category 8.1).

Thirteen non-native freshwater fish species have established populations within the Fraser River basin, yet the majority of these species appear to pose little to no risk to migrating salmonids (Brown et al. 2019). There are, however, several species of note that pose a low level of threat to certain populations, and may become increasingly problematic in the future.

Largemouth Bass (*Micropterus salmoides*) is a voracious piscivore that can consume juvenile salmonids (Brown et al. 2009b), and while they have not become established in the interior Fraser River basin, they currently inhabit the mouths of tributary streams, backwaters, and sloughs throughout the lower Fraser River. A fish-wheel operating in the main-stem Fraser River above Mission BC in 2009-2010 caught 32 Largemouth Bass (Brown et al. 2019). The number of bass residing within the lower Fraser River is unknown, however the species appears to be well-established and thriving. Smallmouth Bass (*Micropterus dolomieu*) is another invasive piscivore present in the Fraser River basin, however they are currently not distributed in areas where FRS are likely to be impacted. In 2006, Smallmouth Bass were found in Beaver Creek, a tributary of the Quesnel River, leading to the intervention by the Province of BC in 2007 (L.M. Herborg, Province of British Columbia, Victoria, BC, pers. comm. 2019). Despite the mitigation efforts, it is likely Smallmouth Bass will eventually move downstream into the Quesnel River, potentially impacting FRS from DU16 (Quesnel-S) and others downstream (Tovey et al. 2009; DFO 2011).

Yellow Perch (*Perca flavescens*) is a species of note that could have potentially significant impacts on FRS in the future. They are a highly adaptable species that utilize a wide range of habitats (Brown et al. 2009a), and are becoming an increasingly abundant threat within areas of the Fraser River basin. Perch juveniles tend to bottom-feed, and larger perch will consume fish eggs and fish (Brown et al. 2009a). When introduced into small lakes, Yellow Perch can have severe impacts on native fish species, largely as a result of competition for food (Bradford et al. 2008; Brown et al. 2009a). Nine small interior lakes were rotenone treated during 2008-2010 to eradicate the populations of Yellow Perch (L.M. Herborg, Province of British Columbia, Victoria, BC, pers. comm. 2019). In recent years Yellow Perch abundance in Nicola Lake has grown substantially and efforts are underway to reduce their numbers. In 2020 the Upper Nicola Band reported recent suppression efforts led to catches of up to ≈ 400 Yellow Perch per day (Chuck Parken, DFO pers. comm. 2020), indicating the current population is substantial and may be expanding.

As discussed in section 3.1.3, FRS migrate rapidly from the pelagic waters of their nursery lakes to the Fraser estuary, and thus have a limited period of time where they are vulnerable to predation in the lower Fraser River. It is possible that outbound juvenile FRS are encountered by invasive predators in the lower Fraser en route to the ocean, yet they are not anticipated to pose a noteworthy threat to the majority of FRS DUs. FRS from DU10 Harrison (U/S)-L are unique in that following emergence they travel downstream from spawning grounds in Weaver Creek and migrate upstream into Harrison Lake where they over-winter, and move to marine waters the following year. This period of migration (both upstream and downstream) potentially exposes fish to predation in clear and slack water areas between Weaver Creek and Harrison Lake and is anticipated to have a low level of impact to the DU (1-10% decline). In addition, FRS from DU24 Widgeon-RT, the only ocean-type variants considered in this RPA, are thought to have the longest residence time in the lower Fraser River prior to ocean migration (see section 3.1.2). During this early rearing period they are likely exposed to invasive predators in backwaters and sloughs of the lower Fraser, and is anticipated to have a low level of impact (1-10% decline).

While not considered in the threat ranking, the establishment of Zebra (*Dreissena polymorpha*) and Quagga (*Dreissena rostriformis bugensis*) mussels pose a serious threat to aquatic ecosystems and some infrastructures in the province. Dressenids are known as ecosystem engineers and couplers of benthic and pelagic habitats (Crooks 2002; Karatayev et al. 2002), and can restructure energy and nutrient fluxes throughout ecosystems producing fundamental changes in food web structure (Higgins and Vander Zanden 2010). Dressenids have a short maturation time (1-2 years) and high fecundity (>1 million eggs/female in each spawning event), with tremendous dispersal abilities at all life stages (Ludyanskiy et al. 1993), compounding the threat to the Fraser River basin and potentially the entire province of BC. The threat of Dressenid mussels was not scored for this category, but it represents a potential future threat due to the severity of risk these mussels can pose if established. Northern Pike (*Esox lucius*; subsequently referred to as Pike) may also pose significant future threats if further expansion into BC occurs. Pike are voracious opportunistic predators, and invasive populations can cause significant top-down pressure on native fish community structure through predation and competition for resources. Pike have been shown to preferentially prey on juvenile salmonid species (Rutz 1999), and invasive populations in Southcentral Alaska have been linked to significant declines in once abundant salmon populations (Haught and von Hippel 2011). Pike have recently colonized the Columbia River and are currently distributed between the Hugh L. Keenleyside Dam near Castlegar, BC, and the Grand Coulee Dam at the lower reach of Lake Roosevelt in Washington state (Doutaz 2019). If Pike move beyond the Grand Coulee Dam they could spread into systems such as the Okanagan River and further into BC.

The European Green Crab (*Carcinus maenas*) has been introduced to coastal ecosystems around the globe, including the Pacific Coast of North America, where they are known to have negative impacts on eelgrass habitats (Howard 2019). Eelgrass meadows provide critically important habitat for juvenile salmon that rear in the estuary (which includes DU24 Widgeon-RT), with habitat features that provide both cover and foraging opportunities in the nearshore environment (Kennedy et al. 2018). Green Crabs can both shred blades and dislodge whole plants through bioturbation while foraging for prey, causing rapid degradation of eelgrass meadows with high crab densities (Howard 2019). There have been significant losses of eelgrass meadows along the Atlantic coast linked to Green Crab abundance. A study conducted in Placentia and Bonavista bays, Newfoundland, reported reductions of eelgrass cover of 50% between 1998 and 2012, and up to 100% in areas with the longer-established and higher-density Green Crab populations. Green Crab is currently found along the entire West Coast of Vancouver Island from Barkley Sound to Winter Harbour with isolated, potentially ephemeral, populations in the Central Coast (DFO 2019[12]). A controlled enclosure study conducted in Barkley Sound demonstrated 73-81% more rapid reductions of eelgrass cover in the presence of high densities of Green Crabs when compared to low density or control treatments (Howard 2019). There have also been reports of Green Crab in the Salish Sea, with detections in Sooke Basin, Beecher Bay, Esquimalt Lagoon, Witty’s Lagoon, Salt Spring Island (2 locations), and Boundary Bay (P. Menning, DFO pers. comm. 2019). DNA analysis is currently underway to determine the source population for these early invaders, the results of which will potentially help inform what future distribution expansions of Green Crab may look like in BC.

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[12] DFO. 2019. European Green Crab.

4.1.8.2. Problematic Native Species

This threat category includes harmful plants, animals, pathogens, and other microbes that are originally found within the ecosystem(s) in question, but have become “out-of-balance” or “released” directly or indirectly due to human activities (IUCN-CMP threat category 8.2).

There are many predators and pathogens of FRS, yet the majority of these interactions are considered to be natural limiting factors rather than threats (see section 4.3). Species discussed in this category are considered to be out of balance as a result of anthropogenic activities. In the past marine mammals (particularly pinnipeds such as Steller Sea Lions and Harbour Seals) were culled to reduce competition with human fisheries, but by the 1970’s marine mammal protection programs were adopted and abundances have since increased significantly (Peterman et al. 2010). Net-pen aquaculture is also discussed in this section, as these operations create unnatural environments with high densities of fish that promote infections and increase prevalence of pathogens (Bakke and Harris 1998; Bass et al. 2017).

Steller Sea Lion abundance in BC has more than quadrupled since 1970, and current abundance in BC (based on pup production) and adjacent waters of Southeast Alaska is approximately 60,000 animals (Olesiuk 2018; Brown et al. 2019). An estimated 35,600 (range 33,800 to 36,700) sea lions currently inhabit the coastal waters of BC during the summer breeding season, and the authors also indicate abundance could potentially be higher, suggesting the time of year the enumeration was conducted could have influenced estimates (Olesiuk 2018). Steller Sea Lions range widely in coastal waters, but during summer the majority congregate at traditional breeding rookeries, the largest of which are found in the Scott Islands off the north end of Vancouver Island, and at Forrester Island, Alaska just north of Haida Gwaii (Queen Charlotte Islands) (Brown et al. 2019). Studies using prey remains found in scats collected at these rookeries and other haul-out sites indicate that Steller Sea Lions feed on a variety of fish and cephalopods, and that salmon constitutes a significant portion of their overall diet. It has been suggested that Steller Sea Lions in BC may be having a more significant role in the declines of FRS than previously considered, with the current population potentially consuming in excess of 300,000 metric tons of fish per year (Walters et al. 2020). Using data from previous research on Steller Sea Lion diet (Winship and Trites 2003; DFO 2012), Sockeye Salmon body size (Jeffrey et al. 2016), and Steller Sea Lion abundance (Olesiuk 2018), Walters et al. (2020) estimated that over a 28-day period in 2013 (during peak migration), Steller Sea Lions could have potentially consumed 1.4 million adult Sockeye Salmon. They compare this estimate to previously reported values of the proportion of Sockeye within Steller Sea Lion scat samples (approximately 9%; Tollit et al. 2009), and suggest that if that was indeed the average percentage of Sockeye Salmon in the July–August diet of the estimated Steller Sea Lion population (33,600 averaged across all British Columbia rookeries in 2013), it would imply approximately 1.3 million Sockeye Salmon were eaten per year. The authors acknowledge these are theoretical values based on data from previous studies but highlight the potential for significant depensatory effects from predation and the need for research on interactions of Steller Sea Lions with FRS (discussed further in Appendix C).

Harbour seal abundance along the Pacific coast has increased dramatically since harvests ended in the late 1960s (Brown et al. 2013[13]). After the mid-1970s, Harbour Seal abundance in the Strait of Georgia increased at a rate of approximately 11.5% per year before stabilizing in the mid-1990s at about 40,000 animals (Brown et al. 2019). This trend is typical of the BC coast

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[13] Brown, G., S.J. Baillie, M.E. Thiess, J.R. Candy, C.K. Parken, G. Pestal, Willis, D.M. 2013. Pre-COSEWIC review of southern British Columbia Chinook salmon (*Oncorhynchus tshawytscha*) conservation units, Part II: Data, analysis and synthesis. Centre for Science Advice Pacific Working Paper 2012/13 P23. Unpublished.

generally, with abundance estimated at approximately 105,000 animals (Olesiuk 2010). There is evidence to suggest that while Harbour Seals primarily consume adult salmon of lesser conservation concern species in the fall season (i.e., Chum and Pink Salmon), they may be a significant contributor to FRS mortality, particularly on larger-bodied out-migrating juveniles at ages >1 (e.g. all lake-type FRS that rear in freshwater for 1 year). Harbour Seal scat samples showed significantly higher percentages of juvenile Sockeye, Chinook, and Coho in the Strait of Georgia compared with Chum and Pink salmon despite higher abundances and increased availability of juvenile Chum and Pink salmon, suggesting seals may be selecting for older, larger salmon smolts that are more profitable to pursue (Beamish et al. 2012; Thomas et al. 2017). Using an example with Coho Salmon, Thomas et al. (2017) highlight the potential impacts on juvenile abundance if Harbour Seals are actively targeting out-migrating smolts, suggesting the estimated 40,000 Harbour Seals in the Strait of Georgia consuming a mean of 2 kg per day could consume 5.7 million smolts in one month (95% CI = 1.4–11.1 million), assuming the average hatchery smolt weighs 20 g, and seal diet is roughly 5% Coho smolts. The authors also acknowledge considerably more smolts could be consumed if the smolts were smaller (e.g., wild Coho smolts). While these are theoretical estimates, diet analysis for Harbour Seals showed similar predation rates for juvenile Sockeye Salmon (2.5% diet) compared to juvenile Coho Salmon (2.9% diet), suggesting predation could lead to large impacts (Thomas et al. 2017). It has also been suggested Harbour Seals may be consuming larger numbers of juvenile salmon in recent years due to increasing numbers of smolts being physically compromised by pathogens (among other factors), implying that seals are only the proximate cause of mortality (see following section; Godwin et al. 2015; Thomas et al. 2017). In addition to impacts on juvenile FRS, Harbour Seal predation on adult Sockeye may also be significant. Thomas et al. (2017) report adult FRS comprised up to 25% and 24% of Harbour Seal diet in July and August (2012), respectively. The impacts at the DU or even MU level are currently unknown for FRS, yet we highlight that for many of the Endangered of Threatened DUs (i.e. all DUs considered in RPA), particularly those with low abundances, the impacts of predation may be significant given the level of predation observed in the above example.

Salmonid fish are host to many infectious agents including viruses, bacteria, fungi, protozoans, helminths, and arthropods (Kent 2011), yet it is challenging to study the prevalence and impact of pathogens in wild salmon populations as they inhabit geographically large environments, and mortalities often go unnoticed due to predation and disappearance (Bakke and Harris 1998). Pathogens and disease may be associated with chronic infections that can impact behavior, condition, and performance that can cause fish to be less capable of continued migration and/or more vulnerable to predation or starvation (Miller et al. 2014). Many of these parasites are opportunistic and do not impact survival unless fish are also stressed by other factors impacting immune system function, such as poor water quality or toxins (Barton et al. 1985; Miller et al. 2014). Pacific salmon are semelparous, and mature, senesce, and starve while migrating back to freshwater, which reduces their condition and ability to fight infection, and makes them especially vulnerable to additional environmental stressors and disease (Miller et al. 2014). Immunosuppression induced by maturation hormones (Pickering and Christie 1980) may also contribute to enhanced susceptibility by even opportunistic parasites or those previously at a carrier state (Miller et al. 2014). As with predatory interactions discussed in the previous section, disease is a natural process that is generally considered to be a natural limiting factor (see section 4.3); however, extensive net-pen aquaculture operations along the coast of BC, particularly in the Discovery Islands area, have been identified as an unnatural source of disease that may be contributing to FRS declines. In the marine environment of BC, there are 109 licensed salmon farm sites with approximately 60 to 70 farms actively operating at a given time (Gross et al. 2019). Many of these operations exist within a major migratory corridor for

FRS, and the unnatural living conditions within net-pens, paired with high densities of fish in close proximity, poses a potential risk for disease transmission between farmed and wild fish.

The impacts from net-pen operations have been an area of debate for many years. In 2012, the Cohen Commission (Cohen 2012c) recommended that these salmon farming operations cease by September 2020 unless there was sufficient evidence to suggest they posed no more than a minimal risk to Fraser Sockeye. In response to the Cohen Commission report, a total of nine peer-reviewed risk assessments were conducted in recent years to investigate a variety of pathogens identified to pose a potential threat to FRS, all of which have indicated disease transmission poses a minimal risk to FRS[14]. These pathogens include: Infectious Hematopoietic Necrosis Virus (IHNV); Aeromonas salmonicida and furunculosis; Piscirickettsia salmonis and salmonid rickettsial septicaemia; Renibacterium salmoninarum and bacterial kidney disease; Yersinia ruckeri and enteric redmouth disease; Piscine Orthoreovirus (PRV); Moritella viscosa; Tenacibaculum maritimum; and Viral hemorrhagic septicemia virus (VHSV). We note that there are more than 40 infectious agents that are suspected to cause disease in salmon worldwide (Kent et al. 2014), and the cumulative effects from these many pathogens, including to those listed above, may be higher than is indicated in these risk assessments.

An exception to the recent risk assessments was Sea Lice, a ubiquitous parasite of salmon that has emerged in recent years as a potentially important factor in Pacific Salmon declines. Net-pen aquaculture provides anomalous over-wintering host populations of parasites such as Sea Lice (Morton and Routledge 2016), ultimately reducing allopatric barriers that served to protect wild fish from infection during the early marine phase (Connors et al. 2010). Research has shown juvenile FRS that migrate through the Discovery Islands corridor carried up to an order of magnitude more sea lice than did Sockeye migrating through a region without farms (Price et al. 2010, 2011). There are two main varieties of Sea Lice that infect FRS: Lepeophtheirus salmonis, a salmonid specialist, and Caligus spp., a more generalist parasite that targets multiple fish species (Godwin et al. 2015). The generalist nature of Caligus spp. is thought to contribute to higher levels of infection in juvenile FRS, and high levels of infection in other fish species such as domesticated salmon or Pacific Herring (Clupea pallasii) that may exacerbate impacts on FRS by serving as secondary reservoirs for infection (Morton et al. 2008; Beamish et al. 2009; Godwin et al. 2015). Direct mortality of FRS from Sea Lice infection is not anticipated to be high, yet there is evidence to suggest infections can lead to indirect reductions in fitness that can influence survival (Godwin et al. 2015). Several potential mechanisms by which sea lice might reduce juvenile Sockeye fitness (e.g. reduced competitive ability, predator avoidance) have been put forth, including visual/swimming impairment, reduced stamina, and antagonistic behaviour from larger or more dominant fish (Godwin et al. 2015). Infected juvenile salmon are also known to occupy peripheral positions of schooling fish, leading to potentially higher levels of risk for predation (Krkošek et al. 2011). The level of Sockeye predation by pinnipeds may be exacerbated by high levels of Sea Lice infection, particularly for outbound juvenile FRS that appear to be targeted by Harbour Seals (discussed in previous section). There is considerable uncertainty surrounding the impacts of Sea Lice on FRS, and the absence of a peer-reviewed risk assessment is a noted research need (Appendix C).

There is also concern surrounding the wastes generated from net-pen aquaculture, which are broadly categorized as organic and inorganic (Ayouqi et al. 2021). Organic wastes from salmon faeces and uneaten feed result in elevated levels of particulate organic carbon, nitrogen, and phosphorus (Wang et al. 2012), while inorganic matter such as ammonium and phosphate arising from metabolic and respiration processes occur as dissolved inorganic nitrogen and phosphorus, respectively (Reid et al. 2013; Ayouqi et al. 2021). Organic enrichment increases

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[14] Fisheries and Oceans Canada. 2020. Summaries of the risk assessments for the Discovery Islands area.

oxygen consumption in the sediment and water column, and the resulting decrease in oxygen concentration, paired with physical smothering of organisms, can alter the local bacterial and benthic invertebrate pathways and degrade the local ecosystem (Backman et al. 2009; Wang et al. 2012; Ayouqi et al. 2021). Further to this, oxygen depletion facilitates the release of hydrogen sulfide from sediments, which is toxic to all fish (Hargrave 2010).

While there is considerable uncertainty surrounding the aforementioned effects of pinniped predation and disease associated with open net-pen aquaculture, all FRS DUs are anticipated to be impacted. It was felt that while there is the potential for predation and disease to have a low level of impact (i.e. <10% population-level decline), there is the possibility of cumulative effects (e.g. infections reducing predator avoidance and competitive ability) that lead to greater, albeit more uncertain impacts (1-30% population-level decline). As discussed in section 3.1.4, the majority of FRS (mostly lake-type variants) rapidly migrate north out of the Strait of Georgia, and either along the east side of Vancouver Island or the coast of BC. Conversely, ocean-type variants have a longer residence in the Strait of Georgia and are thought to mostly exit the via the southern Juan de Fuca Strait to the ocean. These two different migratory routes lead to differential exposure of these fish to aquaculture operations, and it has been hypothesized that ocean-type Sockeye are not experiencing declines to the same degree as lake-type FRS due to the decreased exposure to aquaculture (Morton and Routledge 2016). It is also possible that the extended residence time in the Strait of Georgia may increase the risk of pinniped predation for ocean-type Sockeye compared to lake-type Sockeye that rapidly transit the area. Despite differences in life history and exposure, the same level of impact (1-30%) was chosen due to the small population size, as even losses of modest numbers of fish can amount to a significant overall decline.

4.1.8.3. Introduced Genetic Material

The threat from introduced genetic material includes human altered or transported organisms or genes, which encompasses the genetic effects from hatchery salmonids (IUCN-CMP threat category 8.3).

The threat of introduced genetic material mainly pertains to hatchery or enhancement activities where hatchery-origin and wild fish interact. Hatchery enhancement has become an important tool for increasing the harvest of exploited fish species and augmenting or restoring depressed wild populations (Ford et al. 2002). However, despite salmon enhancement being effective at producing fish for harvest, it remains unclear whether these programs are a benefit, or an impediment, to the recovery of imperilled wild populations (Chilcote et al. 2011; Price 2012). Enhancement and hatchery programs can reduce genetic diversity in hatchery-origin fish by producing cohorts from smaller gene pools and exposing them to different selective, and unnatural pressures found in hatchery environments (Gardner et al. 2004; Grant 2012). Hatchery-origin fish can then interbreed with wild stocks, leading to a decrease in fitness, and limiting population adaptability in future generations due to the reduction of genetic diversity (Waples 1991; Gardner et al. 2004).

Hatchery enhancement has been conducted historically for several FRS DUs (e.g. Chilko (DU3, DU4) and Adams (DU18) lakes), and two hatchery programs are still active for Cultus Lake (DU6 Cultus-L) and the Upper Pitt River (DU15 Pitt-ES; Cohen 2012b; COSEWIC 2017a), yet the vast majority of current enhancement activities involve the use of spawning channels to increase egg-to-fry survival (Stephen et al. 2011; Cohen 2012a; COSEWIC 2017a). However, following the Big Bar landslide in the mainstem Fraser River (2018), hatchery enhancement has been initiated for the most at-risk FRS DUs, DU2 Bowron-ES and DU20 Takla-Trembleur-EStu. In 2019, 177 adult Early Stuart Sockeye were collected from the Fraser River below the landslide and transported to the Fraser Valley, where they were held until they matured and eggs and milt could be collected[15]. These eggs were incubated and reared at Inch Creek Hatchery until October 2020, and then released within areas of the Stuart River watershed. In 2020, adult Early Stuart (n=360) and Bowron (n=44) Sockeye were captured below the Big Bar slide and transported to the Cultus Lake Research Laboratory. Subsequent fry will be released back into historic spawning locations in both the early and late summer of 2021. Unsuccessful attempts were also made for brood stock collection within DU22 Taseko-ES, and there will likely be continued attempts in future years given its low abundance. These hatchery enhancement activities are largely attempts to prevent extirpation of these DUs, yet there is also substantial concern about the effects of hatchery production on genetic diversity and fitness (Murphy et al. 2020). The impacts of these activities at the DU-level are currently unknown and are not considered in the threat ranking, yet we highlight this as a source of uncertainty that requires future research.

Unlike hatcheries that incubate fish eggs and rear juveniles under artificial conditions, spawning channels enable sexual selection based on phenotypic differences during spawning, which significantly decreases the chance of negative genetic effects on adjacent wild populations (Kynard et al. 2011; Price 2012). However, in some cases unplanned events or actions related to the operation of spawning channels may lead to selective spawning pressures that could have genetic effects. For example, FRS from DU16 Quesnel-S have been delayed by the diversion fence in the Horsefly Spawning channel, forcing them to spawn downstream of their natal habitat in the upper reaches of the system. DU10 Harrison (U/S)-L is a stock that was rebuilt with a spawning channel after being driven to near-extinction in the mid 20th century, and nearly all Sockeye from this DU now spawn within the channel rather than natal habitat within the Weaver watershed. There is currently no information to suggest there are negative genetic impacts at the DU-level for these populations, nor are they scored as a threat in the RPA, yet we highlight the potential for unnatural selective pressures in any scenario where spawning or rearing is influenced by anthropogenic factors.

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[15] Big Bar landslide response information bulletin.16 October 2020

Table 23. DFO threats assessment calculator results for impacts from Invasive Non-Native and Alien Species for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Invasive Non-Native and Alien Species

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU10 Harrison (U/S)-L	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Continuous	Extensive

Table 24. DFO threats assessment calculator results for impacts from Problematic Native Species for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Problematic Native Species

Designatable Unit (DU)	**Likelihood of Occurrence**	**Level of Impact**	**Causal Certainty**	**Threat Risk**	**Threat Occurrence**	**Threat Frequency**	**Threat Extent**
DU2 Bowron-ES	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU10 Harrison (U/S)-L	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU14 North Barriere-ES	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive

Table 25. DFO threats assessment calculator results for impacts from Introduced Genetic Material for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Introduced Genetic Material

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU2 Bowron-ES	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Recurrent	Extensive

4.1.9. Pollution and contaminants

IUCN-CMP threat category 9.6, Excess Energy, was not included in this section as there is likely no impact on FRS.

Much of the information in the following sections on pollution were summarized in recent RPAs for Interior Fraser Coho Salmon and Fraser Chinook Salmon. The information provided in these reports is highly relevant to FRS due to their habitat overlap within the Fraser River drainage.

Threats from pollution include introduction of exotic and/or excess materials or energy from point and nonpoint sources, including nutrients, toxic chemicals, and/or sediments. Many sources exist for the Fraser River drainage, therefore pollution is broken into multiple categories which include: Household Sewage & Urban Waste Water; Industrial & Military Effluents; Agriculture & Forestry Effluents; Garbage & Solid Waste; and Airborne Pollutants. Contaminants from within these categories include suspended solids, road salts and sand, ammonia and other nitrogen-based chemicals, phosphorus-based chemicals, heavy metals (e.g. copper, zinc, arsenic, etc.), phenols, poly-aromatic hydrocarbons (PAHs) and other hydrocarbons, endocrine-disrupting chemicals (e.g. hormones like estrogen, plasticizers like phthalates and phenolic compounds, some heavy metals like cadmium), pesticides, herbicides, and organohalogens (e.g. polychlorinated biphenyls (PCBs)). Many of these contaminants are generated from multiple sources and accumulate as mixtures in the environment, therefore the effects from each are extremely difficult to ascertain from one another. In this section the potential effects of contaminant exposure on FRS are first discussed, followed by known sources of pollution from individual categories and their predicted threat to FRS.

Many contaminants persist in the environment, may travel long distances, and have a tendency to accumulate in sediments and food chains. For example, persistent organic pollutants (POPs) such as PCBs, PAHs, and other organohalogens (e.g. DDT and dioxin) from industrial and agricultural discharge produced before the 1980s are still present in Fraser River sediments (higher concentrations in lower Fraser River), and were even found in burbot (Lota lota) in Chilko, Nicola, and Kamloops lakes (Garette 1980; Gray and Tuominen 1999). In the Nechako River, POPs have been detected in sediments of the mainstem and most of its tributaries (Owens et al. 2019), and historical use of other persistent organic pollutants (POPs; e.g. dieldrin, HCHs, chlordanes, endosulfans and toxaphene) in the basin has been found in fish muscle tissues (Raymond and Shaw 1997). PCB concentrations may be highest in estuaries due to sediment deposition by rivers, but have also been found in the headwaters of the Fraser River (Gray and Tuominen 1999). The likely source of these POPs at higher elevations, is long range atmospheric transport and deposition coupled with the release of historic deposits of contaminants from melting glaciers and permanent snowfields. These contaminants are not only from local sources; transport time of atmospheric contaminants from Asia to North America is estimated to be as little as 5-10 days (Ross et al. 2013). In a warming global climate, the release of contaminants from glacial deposits into headwaters may increase and expose younger more vulnerable stages of FRS to POPs. Additionally, PCBs and other POPs are still present in consumer products, and even though they are produced at much lower rates, their persistent nature allows them to accumulate in environments.

For all categories of pollution, with the exception of Garbage & Solid Waste (4.1.9.4), the same rationale for the threat ranking and Causal Certainty is used from previous RPAs on Pacific salmon returning to the Fraser (Fraser Chinook Salmon, Interior Fraser Coho). While there is some evidence linking a variety of pollutants to a population-level decline for FRS and Pacific salmon returning to the Fraser watershed (Medium level of Causal Certainty), there is little in the way of in-situ data surrounding the DU- or even MU-level impacts leading to high levels of uncertainty in the threat rankings. For Garbage & Solid Waste, there is theoretical evidence to suggest population-level declines for FRS (Low level of Causal Certainty), yet there is no quantifiable data to support this link. The threat ranking and associated uncertainties are highlighted in further detail in each section.

4.1.9.1. Household Sewage and Urban Waste Water

This section includes threats from water-borne sewage and non-point runoff from housing and urban areas that include nutrients, toxic chemicals and/or sediments (IUCN-CMP threat category 9.1).

The area surrounding the lower Fraser River is highly concentrated with urban development, and as such, the surrounding area generates considerable sewage and wastewater that enters the Fraser River and its tributaries. The highly impermeable urban landscape of Metro Vancouver and its extensive network of plumbing outflows divert effluents directly through sewer systems, combined sewer outfalls (CSOs), and wastewater treatment plants (WWTPs) including those at Annacis Island (Delta), Lulu Island (Richmond), Iona Island (Richmond), Lions Gate (West Vancouver), and NW Langley (Langley) in the lower Fraser River. Some of these facilities have been upgraded to reduce the amount of contaminants in discharge and to increase capacity to accommodate the human population in Metro Vancouver, yet when wastewater volume exceeds their working capacity, these effluents will bypass treatment plants through CSOs directly entering the Fraser River. In 2016, Metro Vancouver released over 30,000,000 cubic meters of untreated sewage in the Fraser River, making BC the province that consistently has the highest outflow volume in Canada (Cruickshank 2018[16]; Li and Cruickshank 2018[17]). Heavy metals, such as copper from vehicles, can accumulate on roads and then enter CSOs. Dust from roads and highly trafficked areas can also act as a vector of fine sediments and contaminants (e.g. PAHs and heavy metals) to aquatic systems (Gjessing et al. 1984). As noted, Metro Vancouver has the largest population and amount of effluents, but contaminants can travel great distances and accumulate from a variety of sources. The threats from urban contaminants depend on every cities' sewage systems and waste water treatment in both the Fraser River watershed and any city that has outflow into the Georgia Basin. For example, the WWTP in Kamloops includes tertiary treatment (lagoons with biological nutrient removal), whereas Victoria has no fully operational treatment facilities yet. A more thorough assessment of this threat will require collaboration with municipalities and Environment and Climate Change Canada.

Urban pollution is an extensive threat for all FRS DUs, as all Sockeye must all migrate through the lower Fraser River twice and sometimes rear as juveniles for a extended periods of time (i.e. ocean-type). FRS from DU24 (Widgeon-RT) are likely most exposed to urban pollution due to their extended residence time in the lower Fraser before ocean migration. FRS that migrate through populated areas further upstream (e.g. DU16 Quesnel-S, DU20/DU21 Takla-Trembleur-EStu/Summer) may also encounter sources of urban pollution leading to additional impacts. There is evidence to suggest exposure to household and urban contaminants (e.g. pharmaceuticals, home and personal care products, etc.) leads to adverse effects, both direct and indirect, yet it is difficult to separate these effects from concurrent factors. As a result, there is considerable uncertainty in the aggregated level of impact so an uncertainty range of low-medium was chosen to represent this (1-30% decline). The group felt losses in excess of 10% were plausible in the event of a serious pollution event, particularly for DUs with extremely low abundances (i.e. DU24 Wigeon-RT).

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[16] Cruickshank. 2018. News article for The Star *Vancouver: "Untreated sewage pollutes water across the country".*

[17] Li and Cruickshank. 2018. News article for StarMetro*: "Sewage problems must be fixed if Vancouver wants to be a global role model, say advocates*".

4.1.9.2. Industrial & Military Effluents

This section includes water-borne pollutants from industrial and military sources including mining, energy production, and other resource extraction industries that include nutrients, toxic chemicals and/or sediments (IUCN-CMP threat category 9.2).

Many industrial effluent outflows connect to municipal sewage systems, WWTP, and CSOs, but some facilities may also have their own treatment systems on site. Numerous treatment facilities were upgraded during 1980-2000 to reduce the amount of contaminants discharged. Paper and pulp mill effluents make up the largest proportion of industrial discharges in the Fraser River watershed (Gray and Tuominen 1999) and often have on-site treatment facilities. Federal and provincial legislation enacted in the late 1980s and 1990s increased required effluent monitoring programs and treatment of discharge to reduce the levels of dioxins, furans, and other total suspended solids, sometimes reducing them by up to 99%. Wood preservative facilities contributed to a large proportion of non-pulp mill industrial discharge, using antisapstain fungicides such as dodecyl dimethyl ammonium chloride (which is also used as a pesticide in BC). Again, legislation and operational changes have decreased the quantity of antisapstains discharged by around 99% relative to the mid-1980s (Gray and Tuominen 1999). Treated lumber, railway ties, pilings, and utility pole construction use/ chemicals such as creosote, pentachlorophenol, chromated copper arsenate, and ammoniacal copper arsenate; many direct discharges were reduced by ~90% since the mid-1980s (Gray and Tuominen 1999). Unfortunately, historical seepage of creosote into soil from historical operations resulted in significant underground reservoirs of contaminants that are slowly infiltrating systems through groundwater.

Mining activities (particularly metal mining) have the potential to adversely affect environmental conditions if proper mitigation is not in place. There are 7 metal mines in the Fraser River watershed. Six of these mines conduct open pit mining: Endako (Prince George area); Huckleberry (Houston area); Gibraltar (between Williams Lake and Quesnel); Mount Polley (near Williams Lake); Quesnel River (near Quesnel); and Highland Valley (near Kamloops). One mine, Bralorne (Bridge River area), is an underground gold mine. The Endako mine discharges wastewater into a creek that drains into Francois Lake and then into the Endako River, which drains into Fraser Lake. The Huckleberry mine discharges into the Tahtsa Reach on the Nechako Reservoir, which has two discharge points (it is unclear how much discharge enters the Fraser River). Intentional and unintentional releases from mines include contaminants such as conventional variables, microbiological variables, major ions, nutrients, metals, cyanides, petroleum hydrocarbons, monoaromatic hydrocarbons, and polycyclic aromatic hydrocarbons. There are also closed/abandoned mines in the Fraser River watershed. Accidental spills from mine tailings and transportation of resources may have impacts on FRS in the Fraser River. The recent Mt. Polley mine tailings pond breach may have several negative impacts on FRS from DU16 (Quesnel-S) that use Quesnel Lake, its tributaries, or migrate through it for years to come. The breach released approximately 25 million m^3 of copper and gold mine tailings material into Polley Lake, Hazeltine Creek, and Quesnel Lake (Klemish et al. 2019). Between the occurrence of the disaster and September 2018, an additional 10.8 million m^3 of effluent was estimated to have been released into the west arm of the lake (MPMC 2018), and continues to impact the Quesnel Lake ecosystem (discussed in detail in section 4.1.3.1). The acute changes in turbidity and other suspended pollutants can cause physiological trauma (such as gill abrasions), increased incidence of disease, and behavioural changes (Bisson and Bilby 1982; Nikl et al. 2016). If copper sediments remain suspended or become suspended, there may also be impacts to juvenile salmonids chemosensory systems that may have lasting and detrimental behavioural effects (Sandahl et al. 2007). Metal concentrations in water, sediment, and fish tissues have been consistent with concentrations in other studies that elicited metal toxicity, the effects of which include mortality, decreased growth, and chemosensory impairment in aquatic biota (Klemish et al. 2019). FRS and Rainbow Trout in the west arm of Quesnel Lake have been found to accumulate metals at concentrations known to be toxic to other fish species, and the diversity of benthic invertebrate communities appear to have declined post-breach (effects on plankton and other aquatic species currently unknown; Klemish et al. 2019). A recurrent and visible "greening" has also become apparent within the lake since the autumn of 2014, which is clearly visible through satellite imagery (Hamilton et al. 2020). Short-term effects were likely limited to Sockeye from DU16, but there could potentially be downstream effects in the future. The long-term impacts on the Quesnel Lake ecosystem are currently unknown but could be significant and detrimental.

Coal dust from production and transport contains abundant particulate matter, heavy metals, and organic pollutants such as PAHs (Mamurekli 2010). Coal dust can enter the environment through storm water discharge, coal pile drainage run-off, air-borne transfer of coal dust during processing/transport (storage piles, conveyor belts, rail cars), and train derailments. Exposure to coal dust extracts can trigger oxidative imbalance in biological systems leading to cellular damage and the development of a wide range of anomalies (Indo et al. 2015; Pizzino et al. 2017). The Roberts Bank Coal Terminal is the largest coal export facility on the Pacific coast of North America, shipping more coal than all other Canadian terminals combined (Westshore 2019)[18]. The coal terminal has had numerous effects on the local ecology of the surrounding area, and the release of coal dust from the terminal has had detrimental impacts on the region (Johnson and Bustin 2006). Local residents as far away as Pt. Roberts (5-10 km) have reported coal dust escaping the terminal from the incoming loaded rail cars, conveyor belts, and returning empty trains during the loading processes (DFO 1978; Johnson and Bustin 2006) indicating significant air-borne transfer into the surrounding environment. FRS are likely exposed to pollution associated with coal dust for a limited period of time in the Fraser River estuary, and lower sections of the river where coal production and transport is greatest. The impacts of coal pollution on FRS is currently unknown at the DU-level, but the effects are expected to be negative.

The transport of diluted bitumen (dilbit) through pipelines and coastal areas may have negative impacts if leaks or spills occur. Dilbit products vary in the proportions and types of PAHs, polycyclic aromatic compounds (PACs), and in their molecular weights, resulting in varying embryo toxicities (Alsaadi et al. 2018). This variability therefore increases the uncertainty of the impacts of a dilbit spill. Two studies that examined the toxicity of dilbit on salmon were conducted for Sockeye Salmon parr (Alderman et al. 2017a, 2017b). They found that parr suffered reductions in swimming performance and increased rates of cell damage, which would likely result in increased mortality in subsequent stages. A study on Pink Salmon eggs that were exposed to sub-lethal concentrations of PAHs (not in the form of dilbit) showed a 40% reduction in survival of fry that emerged compared to non-impacted years, with an overall reduction in productivity greater than 50% (Heintz et al. 2000). The TransMountain pipeline runs through the top portion of the upper Fraser River, the length of the North Thompson, part of the Lower Thompson (i.e. the Coldwater River), and along the lower Fraser River. Spills over land may also pose an unknown threat if dilbit or its constituents seep into groundwater and are transported into streams and the hyporrheic incubation environment in low concentrations but over a long period of time. Dilbit is also transported by rail, where trains pose a derailing risk along several routes that run along the middle Fraser, North Thompson, South Thompson, Lower Thompson, and lower Fraser River. Other chemicals are also transported by rail, such as creosote and caustic substances that have the potential to kill hundreds of thousands of fish (Ross et al. 2013). An example of this is the train derailment that occurred along the

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[18] Westshore Terminals. 2019. Premier Mover of Coal.

Cheakamus River in 2005, where 41,000 litres of sodium hydroxide was spilled into the river killing nearly all fish downstream of the spill (Melville and McCubbing 2007). A railway is in operation adjacent to shore within DU17 Seton-L, and along sections of the Thompson and Fraser rivers, and spills directly into streams would likely create acute but catastrophic impacts where they occurred, but also chronic long-term effects if contaminants enter groundwater or accumulate in sediments.

There are a multitude of industrial sources of pollution that likely impact FRS, yet these impacts are difficult to quantify with certainty. There is a growing body of evidence to suggest exposure to a variety of industrial-derived contaminants (PCBs, PCBEs, PAHs, etc.) can lead to both direct and indirect mortality, ultimately influencing survival. All FRS transit the lower Fraser River and estuary twice, and are thus exposed to any pollution in these areas. Additional sources of pollution from development, resource extraction, and transportation upstream of the lower Fraser River may have additional impacts, yet there is currently insufficient evidence to estimate DU-level declines. The Mt. Polley tailings pond breach may lead to significant long-term effects on FRS in the Quesnel drainage, and could pose a significant downstream threat in the future. Due to the many sources of industrial pollution and uncertainty surrounding impacts, an uncertainty range of low-medium (1-30%) was chosen as while the group felt it was plausible for impacts to be less than 10%, there is the potential for higher impacts on all DUs (11-30%) in the event of a major spill event, particularly for DUs with low abundance and single spawning sites (i.e. DU10 Harrison (U/S)-L, DU17 Seton-L, DU24 Widgeon-RT. As with urban pollution, DU24 is likely most threatened from industrial contamination due to their extended residence time in the lower Fraser prior to ocean migration.

4.1.9.3. Agricultural and Forestry Effluents

This threat includes water-borne pollutants from agricultural, silvicultural, and aquatic systems that include nutrients, toxic chemicals, and/or sediments including the effects of those pollutants on the site where they are applied (IUCN-CMP threat category 9.3).

Contamination from agriculture and forestry include sediments, nutrients, and a variety of toxic chemicals such as pesticides and herbicides. Also included in this category is forest fires, which can exacerbate the impacts of effluents from the agricultural and forestry sectors, and introduce toxic chemicals into aquatic ecosystems through forest fire management (i.e. aerial fire retardants).

The frequency and magnitude of sedimentation that may occur from the removal of vegetation through forestry is related to variables like slope, soil composition (including bacterial communities), wind, the extent and method of vegetation removal, precipitation, riparian buffer areas, and the presence of roads (Meehan 1991). It is well established that logging practices may destabilize sediments and increase sedimentation in adjacent and downstream fish habitat with the additional increased risk of landslides that can affect connectivity (Wise et al. 2004). Additionally, fire affected forests and soils can also increase rates of sedimentation and exacerbate the effects of logging. Cattle grazing is another significant source of sediment inputs to streams through bank destabilization and increased surface erosion (Rhodes et al. 1994). Sediments and their effects can be broadly separated into fine and coarse sediments. Fine sediments have more direct impacts than coarse, primarily by reducing egg survival through decreasing oxygen circulation, intrusion of fine sediments and preventing fry from emerging from redds (Chapman 1988; Meehan 1991). Fine sediments also lead to changes in primary and secondary productivity, hyporheic exchange, and flocculation rates, which all interact in complex ways and their impacts are often variable across systems (Meehan 1991; Moore and Wondzell 2005).

Nutrient loading from fertilization of agricultural lands and forestry replanting, or feces from livestock that enriches effluent may also impact juvenile salmon and their habitat. Increases in nutrients and/or organic loading of an aquatic ecosystem can lead to increased biological productivity, sedimentation of unutilized organic matter, and changes in community composition (Likens 1972). Above natural nutrient levels can cause eutrophication and create hypoxic zones in stagnated water that may prevent juvenile salmon from using those habitats (Gordon et al. 2015). There is little evidence that this is occurring in the Interior Fraser (though data exists for analysis through Environment and Climate Change Canada); however, tributaries of the lower Fraser are known to become eutrophic (Gordon et al. 2015). For example, the biological oxygen demand (BOD) from agricultural fecal waste has decreased O_2 levels enough to kill adult Chum Salmon in Chilqua Creek multiple times (C. Parken pers. comm. 2019). Nutrients may also affect primary and secondary productivity in beneficial ways. Nutrient additions have been used to enhance stocks in lakes and streams before, but there are sometimes unintended consequences of increased predation rates that mask benefits (Hyatt et al. 2004a; Collins et al. 2016). There is currently no nutrient enhancement in the Fraser River watershed.

A variety of pesticides and herbicides are used in the agricultural and forestry sectors to control insects, weeds, and fungi, which can have a range of negative effects when introduced into aquatic environments. These chemicals mainly fall in the general categories of organochlorines (e.g. DDT, endosulfan, cyclodienes), organophosphates (e.g. glyphosate aka RoundUp), chlorophenoxies (e.g. 2, 4-D), and triazenes (e.g. atrazine). As noted in the industrial effluent section, organochlorine chemicals are slow to biodegrade and persist in environments. Organochlorine pesticides used before the 1980s (i.e. DDT) are still present in Fraser River sediments (highest concentrations in lower Fraser River) and were also found in burbot (L. lota) in Chilko, Nicola, and Kamloops lakes (Garette 1980; Gray and Tuominen 1999). Other organochlorines (i.e. non-DDT) have also been observed in agricultural ditch water connected to lower Fraser River tributaries that salmon use (Wan et al. 2005). Glyphosate is used in both agriculture and forestry. There are laws that prevent its use near aquatic systems but it can be transported in rain eroded soils and enter streams, though it also degrades quicker when it becomes dissolved in water (Van Bruggen et al. 2018). Therefore, even if glyphosate enters streams, it may not reach concentrations lethal to juvenile salmon (Mitchell et al. 1987). Chlorophenoxy herbicides and triazenes are also transported into streams by rain water but may persist for longer periods than organophosphates and may accumulate in sediments (Hill et al. 1990; Solomon et al. 2008). The above contaminants (and more) have been observed in the interior and lower Fraser River watersheds (Gray and Tuominen 1999), but more consistent and intensive surveys are required to understand their impacts on FRS.

Wildfires are expected to occur with increasing frequency with climate change, resulting in a concurrent increase in fire management. The application of fertilizer-based fire retardants is an important tool in aerial firefighting, yet these chemicals can enter aquatic ecosystems via surface runoff, misapplication from an aerial drop, or during exceptions to the application restrictions during extreme fires (Buhl and Hamilton 1998). Fire retardants contain inorganic salts such as diammonium phosphate and ammonium polyphosphate, and are the primary toxicants that lead to the formation of un-ionized ammonia in the water column (Buhl and Hamilton 1998; Dietrich et al. 2014). Ammonia exists in both ionized (NH_4^+) and unionized (NH_3^0) forms when dissolved in surface water, the former of which does not easily cross fish gills and is less bioavailable than the unionized form (Francis-Floyd et al. 2009). Ammonia can be acutely toxic to fish mainly due to its effect on the central nervous system, also known as "acute ammonia intoxication", which can lead to loss of equilibrium, hyperexcitability, increased breathing, cardiac output, and oxygen uptake, and in extreme cases, convulsions, coma, and death (United States Environmental Protection Agency [USEPA] 1989; Randall and Tsui 2002). Lower concentrations of ammonia can lead to reductions in hatching success, growth rate, and morphological development, in addition to causing pathologic changes in tissues of fish gills, livers, and kidneys (USEPA 1989). Ammonia is also more toxic to aquatic life at higher temperatures (Levit 2010), suggesting smaller streams in areas that experience high temperatures are at an increased level of risk. The cumulative adverse impact of fire retardants includes not only the acute mortality immediately following a misapplication, but also the delayed mortality once exposed salmon enter seawater (Dietrich et al. 2013).

As with the previous pollution categories, there are many sources of agricultural contamination that are anticipated to have negative cumulative impacts on FRS, ultimately reducing survival. This is expected to be true for all FRS DUs, yet due to the lack of research and uncertainty surrounding impacts, pollution related to forestry and agriculture are expected to lead to low-medium level impacts at the DU level (1-30%). It is unlikely DU-level declines are near the high end of the range (30%); however, in the event of a major spill or release of effluents, this number could potentially be higher than 10%. This is particularly true for DUs at low abundance with single or few spawning sites.

4.1.9.4. Garbage and Solid Waste

This threat category includes rubbish and other solid materials including those that entangle wildlife. This includes municipal waste, litter from cars, flotsam and jetsam from recreational boats, waste that entangles wildlife, construction debris, abandoned fishing gear, micro plastics (IUCN-CMP threat category 9.4).

Microplastics are barely visible plastic particulate matter in the form of small fragments, fibres, and granules, and are becoming an important contaminant of concern due to their global abundance and widespread distribution (Desforges et al. 2015). The ingestion of microplastics is considered to be a physical threat as accumulation of plastic can block the intestinal tract leading to mortality. Microplastics also pose a threat to planktonic prey species of salmon, as particles may entangle feeding appendages and/or block or abrade internal organs resulting in reduced feeding, poor condition, injury, and mortality (Cole and Newton 2013). Indiscriminate feeders in the water column maybe at particular risk because they might mistake microplastics for natural food items of the same size (Desforges et al. 2015). It has been suggested that suspension and filter feeding zooplankton are exposed the most to microplastics, as these feeding modes are used to concentrate food from large volumes of water (Kaposi et al. 2014; Moore 2008). Recent research conducted in the Strait of Georgia by Desforges et al. (2015) has provided an ecological context for transmission of microplastics to higher trophic level such as Pacific salmon. This study demonstrated two types of zooplankton critically important to salmon, copepods and euphausiids, are ingesting microplastics in the open ocean, leading to the subsequent accumulation of these contaminants in fish predating on them. The exposure to microplastics may be considerable for Pacific salmon species; juvenile salmon were estimated to consume 2–7 microplastic particles per day, and returning adult salmon were estimated to consume ≤91 particles per day. While the authors conclude this study is speculative, they provide a sense of the possible scale for exposure to microplastics, and raise questions about risks to populations of ecologically and economically important species (Desforges et al. 2015). More recent research on juvenile FRS foraging ecology found microplastics (plastic pieces ≤ 5mm) in 3.1% of all stomach samples (James 2019), indicating there are potential, albeit unknown impacts on FRS survival. Further research is needed in order to quantify the impacts of microplastics on FRS and other Pacific salmon, yet the effects are anticipated to be negative.

Fishing nets, ropes and traps are often lost in storms, snags or when damaged can cause detrimental impacts to fish and other animals when encountered. Lost fishing gear may continue to catch fish in the water column, which in turn can attract predators that may also become entangled. An estimated 800,000 tonnes of fishing gear is lost to the ocean each year, yet it is currently unknown what the extent of lost fishing gear is in coastal waters of BC (Emerald Sea Protection Society 2019)[19].

Further research on the effects of garbage and solid waste (microplastics and abandoned fishing gear) is needed to estimate the level of impacts, therefore a rank of unknown was applied to this threat; however, it is anticipated that overall impacts will be negative for all FRS DUs and will likely increase in the future.

4.1.9.5. Air-Borne Pollution

This threat category includes atmospheric pollutants from point and nonpoint sources. This includes acid rain, smog from vehicle emissions, excess nitrogen deposition, radioactive fallout, wind dispersion of pollutants or sediments, smoke from forest fires or wood stoves (IUCN-CMP threat category 9.5).

Air currents transport airborne chemicals that may be photodegraded by the sun's rays, or deposited to the ground either by wet or dry deposition or by gas absorption (Blais 2005). Some contaminants such as PCBs, dioxins, furans, DDT, dieldrin, chlordanes, and hexachlorobenzene have an extraordinary capacity for long-range transport, as demonstrated by the presence of these contaminants in foodwebs in remote northern regions of Canada where production of these chemicals is absent (Dewailly et al. 1989; Gilman et al.1997; Blais 2005). Other air-borne contaminants such as coal dust from loaded rail cars, conveyor belts, and returning empty trains during loading processes can be introduced into the surrounding environment (Johnson and Bustin 2006). Snowpack accumulation is also an important contributor of contaminants to mountain lakes (Blais et al. 2001), with maximum contaminant loading typically occurring during the snowmelt period (Blais 2005). Snowflakes are very effective scavengers of contaminants from the air (Blais 2005), providing a significant mechanism of transporting anthropogenic-derived pollution through air currents. Some contaminants may volatilize back in the air as the snowpack matures, while compounds with higher water solubility (like HCHs) tend to become dissolved in meltwater and return to the soil as the snow melts (Wania 1997; Blais 2005). Rapid rates of snow-melt typically results in a pulse of contaminants to surface streams and lakes (Blais et al. 2001). The threat from air-borne contaminants to FRS is extensive (Blais 2005). While there is a growing body of evidence suggesting air-borne pollution may contribute to declining environmental conditions, the level of impact for this threat is highly uncertain. As with the previous pollution categories scored, this is scored as a low-medium level impact (1-30%). The group acknowledges that this range is unlikely on the high end (30%) but could potentially be higher than 10% due to the wide-spread nature of air-borne contaminants and their potential contributions to declining environmental conditions.

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[19] Emerald Sea Protection Society 2019. Lost Fishing Gear - A Global Challenge.

Table 26. DFO threats assessment calculator results for impacts from Household Sewage and Urban Waste Water for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Household Sewage and Urban Waste Water

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU2 Bowron-ES	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU10 Harrison (U/S)-L	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU14 North Barriere-ES	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive

Table 27. DFO threats assessment calculator results for impacts from Industrial and Military Effluents for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Industrial and Military Effluents

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU2 Bowron-ES	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU10 Harrison (U/S)-L	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU14 North Barriere-ES	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive

Table 28. DFO threats assessment calculator results for impacts from Agricultural and Forestry Effluents for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Agriculture and Forestry Effluents

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU2 Bowron-ES	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU10 Harrison (U/S)-L	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU14 North Barriere-ES	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Low-Medium	Medium	Low-Medium (3)	Historical/Current/ Anticipatory	Continuous	Extensive

Table 29. DFO threats assessment calculator results for impacts from Garbage and Solid Waste for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Garbage and Solid Waste

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU2 Bowron-ES	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU10 Harrison (U/S)-L	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU14 North Barriere-ES	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Unknown	Low	Unknown (4)	Historical/Current/ Anticipatory	Continuous	Extensive

Table 30. DFO threats assessment calculator results for impacts from Air-Borne Pollution for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Air-Borne Pollution

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU2 Bowron-ES	Known	Low-Medium	Low	Low-Medium (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU10 Harrison (U/S)-L	Known	Low-Medium	Low	Low-Medium (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU14 North Barriere-ES	Known	Low-Medium	Low	Low-Medium (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Low-Medium	Low	Low-Medium (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	Low-Medium	Low	Low-Medium (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Low-Medium	Low	Low-Medium (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Low-Medium	Low	Low-Medium (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Low-Medium	Low	Low-Medium (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Low-Medium	Low	Low-Medium (4)	Historical/Current/ Anticipatory	Continuous	Extensive

4.1.10. Geological events

IUCN-CMP threat category 10.1 Volcanoes, and 10.2 Earthquakes and Tsunamis were not included in this section as these activities are not anticipated to impact FRS.

4.1.10.1. Avalanches and Landslides

This threat includes avalanches, landslides, and mudslides (IUCN-CMP threat category 10.2). Avalanches and landslides are considered as a threat and not a limiting factor, since anthropogenic activities have caused significant declines in FRS abundance, increasing their vulnerability to impacts from landslides.

Landslides can block migration of both adult and juvenile fish, destroy habitat, and alter habitat conditions by introducing unnaturally high concentrations of sediment. Avalanches and landslides can occur naturally or from human driven cumulative impacts, and are expected to increase in frequency in North America with Climate Change (Gariano and Guzzetti 2016). Recent hydrological modeling work projects nearly half of the Fraser River basin (45%) will transition from a snow-dominated hydrograph in the 1990s to a primarily rain-dominated regime by the 2080s (Islam et al. 2019b). The same study projected a nearly 25-day advance of spring freshet by the 2050s, and 40 days by the 2080s relative to the 1990s. This extended freeze thaw period, paired with an increased frequency of rain events, can have profound effects on slope stability and increase the occurrence of landslides. Roads related to forestry have also been attributed to landslides in some systems (Trombulak and Frissell 2000), with years and decades passing before the cumulative impacts to slope stability are realized. If the debris from landslides is not mitigated, landslides have the potential to extirpate entire demes by cutting off passage or burying spawning gravel. The historical slide at Hells gate (1914) and the recent Big Bar landslide (2018) represent the worst case scenario of a landslide.

In late 2018, a significant landslide occurred in a narrow and remote portion of the Fraser River near Big Bar, BC, inhibiting passage to all returning salmon that spawn above the blockage. Approximately 80% of all FRS stocks were impacted by the Big Bar slide (100% Early Stuart MU, 60% of the Early Summer MU, 90% of the Summer MU and 0% of the Late MU; Murphy et al. 2020). FRS DUs covered in this RPA that spawn above the slide include DU2 (Bowron-ES), DU16 (Quesnel-S), DU20 (Takla-Trembleur-EStu), DU21 (Takla-Trembleur-S), and DU22 (Taseko-ES). The Big Bar landslide poses an additional factor exacerbating stressful migratory conditions already experienced by FRS from ecosystems modifications and climate change, ultimately leading to high levels of mortality prior to spawning.

As discussed in section 4.1.7.3, ecosystems modifications within the Fraser River basin has led to significant changes in temperature and flow dynamics that threaten FRS migration, particularly for DUs with earlier migration timing that spawn in the middle and upper reaches of the watershed. In-river survival data for 2019 showed less than 1% survival for the earliest timed stocks, DU20 (Takla-Trembleur-EStu) and DU22 (Taseko-ES); for later migrants including DU16 (Quesnel-S) and DU21 (Takla-Trembleur-S), much higher survival was observed (80%; Murphy et al. 2020). Considerable work has been conducted since the slide event to remedy passage conditions for returning salmon, including the installation of a fish ladder; however, these activities are not anticipated to restore passage to pre-2018 levels (Macdonald et al. 2020). Continued high levels of migration mortality could lead to the potential extirpation of DU20 in the near future, and is thus facing extreme impacts (71-100% decline). The Early Summer DUs (DU2 Bowron-ES, DU22 Taseko-ES) are also at continued risk from the landslide, however, these fish are not expected to experience the same level of impact compared to Early Stuart Sockeye. With mitigations at the slide site, it is possible impacts will be reduced considerably in the future, yet in the event of high flows or temperatures during migration, mortality resulting from attempted passage of the slide could be significant. There is a high level of uncertainty surrounding the future impacts of the slide on these DUs and it was felt the level of impact could potentially be greater than 30%. A medium-high level of impact (11-70% decline) was chosen to represent this uncertainty, with the acknowledgement this is not likely to be at the high end of the range in most years. It should be noted that DU22 is additionally threatened by landslide activity in the lower Chilcotin, which is a relatively unstable watershed following significant fires in the region. Rainfall events can interact with unstable geomorphology of lower canyon, and the event in Farwell Canyon in 2004 is a notable example in which the Chilcotin River was blocked by a large mudslide in addition to adding massive sediment loads into the river. The later run stocks (DU16 Quesnel-S and DU21 Takla-Trembleur-S) are not as threatened from the landslide due to more stable flows and temperatures during their peak migration yet are still anticipated to have medium-level impacts (11-30% decline) considering recent mortality estimates. For all DUs that spawn above the landslide, the longer-term effects on individual fitness, population structure, and future mortalities of adult and juvenile fish due to passage impediment will not be known in the near term.

While below the Big Bar Landslide, DU17 (Seton-L) is anticipated to be impacted from landslides due to ongoing sediment issues in Portage Creek from the November 2016 landslide at Whitecap Creek (footprint in spawning habitat), and there are no alternate spawning grounds. The Seton watershed is prone to episodic landslides that can have significant adverse impacts on FRS from DU17 (Seton-L), and the area is projected to see to a substantial increase in the frequency of extreme rainfall events and a moderate increase in their intensity with climate change (BGC 2018). The most recent and significant events have occurred on Whitecap Creek, a tributary to the Portage Creek that meets 670 m downstream of Anderson Lake, where ongoing sedimentation issues from landslide events threaten Sockeye from this DU. In September 2015 a debris flood and channel avulsion occurred on Whitecap Creek that deposited large amounts of sediment into Portage Creek, resulting in a complete blockage for approximately 170 m that prevented outflow from Anderson Lake and caused flooding around the lakeshore (BGC 2018). The following year in November 2016, another channel avulsion occurred in Whitecap Creek that resulted in an approximate 75% blockage of Portage Creek (BGC 2018). These events occurred in high quality spawning habitat and there are no alternate spawning grounds within the DU. Impacts of this landslide on egg-to-fry survival are currently unknown (Macdonald et al. 2020), but they are anticipated to be negative.

DU10 (Harrison (U/S)-L) is suspected to be at a low level of risk due to the Meager Creek landslide that occurred in 2010, which released approximately 48.5×10^6 m^3 of material in a debris flow that temporarily dammed Meager Creek and the Lillooet River (Guthrie et al. 2012). The landslide created a large sediment plume at the north end of Lillooet Lake that moved south into Harrison Lake over the next year where juveniles from this DU rear. While events like this are uncommon, there would be significant direct impacts in the event of another major landslide in this system. Overall this likely constitutes a low level threat to the DU.

Table 31. DFO threats assessment calculator results for impacts from Avalanches and Landslides for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Avalanches and Landslides

Designatable Unit (DU)	**Likelihood of Occurrence**	**Level of Impact**	**Causal Certainty**	**Threat Risk**	**Threat Occurrence**	**Threat Frequency**	**Threat Extent**
DU2 Bowron-ES	Known	Medium-High	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU10 Harrison (U/S)-L	Unlikely	High	Low	Low (4)	Historical/Current/ Anticipatory	Recurrent	Extensive
DU16 Quesnel-S	Known	Medium	High	Medium (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	High	Medium	High (3)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Extreme	High	Extreme (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Medium	High	Medium (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Medium-High	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive

4.1.11. Climate change

Much of the information presented on FRS in this section is summarized in detail in Grant et al. (2019), *State of Canadian Pacific Salmon: Responses to Changing Climate and Habitats*, which discusses climate change impacts for all the imperilled Pacific Salmon species.

4.1.11.1. Habitat Shifting and Alteration

This threat involves major changes in habitat composition and location, and includes sea-level rise, desertification, tundra thawing, coral bleaching, shifts in the hydrological regime due to climate change (IUCN-CMP threat category 11.1).

Habitat shifting and alteration encompasses a large suite of complex and inter-related issues that threaten all FRS DUs covered in this RPA. These shifts are occurring both in the freshwater and marine environment, threatening FRS at all life stages and in all habitats. This category is broken into two parts and discusses current trends in the freshwater and marine environments. It is noted climate change in the marine environment is discussed as a whole in this section, and includes temperature extremes (i.e. marine heatwaves such as “The Blob”), whereas temperature extremes in freshwater are scored in section 4.1.11.3.

Air temperatures in BC have reached record highs in recent years, and precipitation patterns are becoming increasingly variable with time (i.e. increased frequency and magnitude of storms and rainfall events; (Pike et al. 2010a; Bush and Lemmen 2019; Grant et al. 2019). More frequent periods of prolonged precipitation and warm temperatures are increasing the vulnerability of hillsides to landslides, and also increase the frequency of slide triggers from more intense rain events, changes in the freeze-thaw cycle, and severe shifts from dry to wet conditions (Pike et al. 2010b; Cloutier et al. 2016; Grant et al. 2019). Recent studies have reported changes in runoff timing and magnitude within the Fraser River basin resulting from changing climate, and have indicated an advance of the spring freshet and reduced summer peak flow in the mainstem Fraser and its major tributaries (Shrestha et al. 2012; Kang et al. 2014, 2016; Islam and Déry 2017). Surface hydrology modeling of the Fraser River basin between 1949 - 2006 demonstrated a 19% decline in the contribution of snow to runoff generation for the main stem Fraser River at Hope, owing to a 1.48 °C overall rise in mean annual air temperatures over the study period (Kang et al. 2014). More recent hydrology modeling projects almost half of the Fraser River basin (45%) will transition from a snow-dominated hydrograph in the 1990s to a primarily rain-dominated regime by the 2080s (Islam et al. 2019b). The same study projected a nearly 25-day advance of spring freshet by the 2050s, and 40 days by the 2080s relative to the 1990s. At a regional scale, projections to 2070 show that warming will be greater in the Interior portions of southern BC when compared to the coastal region (Pike et al. 2010; COSEWIC 2017b).

Warmer air temperatures, lower spring snow packs, and receding glaciers are causing river temperatures to rise well above seasonal averages, and temperatures of 18°C - 20°C in summer months are becoming more common in Southern BC, including the lower Fraser (temperature effects scored in section 4.1.11.3; Eliason et al. 2011; Martins et al. 2011; Grant et al. 2019). In snow-dominated hydrological systems in the B.C. Interior and/or northern latitudes, the snow-to-rain ratio is decreasing overall, glacier retreats are accelerating, and lake ice is melting earlier in the spring, resulting in earlier than average peak river flows in the spring (Grant et al. 2019). Rain-dominated systems in coastal BC are also experiencing more extreme conditions, with increased frequency of flood events likely leading to increased egg losses from scouring (flood effects scored in section 4.1.11.4; Holtby and Healey 1986; Lisle 1989; Lapointe et al. 2000).

Environmental conditions in lakes are also changing, which is particularly important for the FRS juvenile rearing stage (Grant et al. 2019). Thermal stratification and primary productivity in lakes has varied consistently in recent assessments when compared to historical data, and has had variable impacts both positive (Chandler et al. 2018; Macdonald et al. 2018) and negative (Bradford et al. 2011; DFO 2018b) for the two populations where these data are available (Chilko (DU3/4) and Cultus (DU6), not considered in RPA; Grant et al. 2019). While there is currently limited information for other FRS DUs, it is likely that other nursery lakes in the Fraser River watershed are experiencing similar shifts in thermal regimes and productivity.

Warmer mean ocean temperatures, reduced sea ice extent, and increased ocean acidification are all contributing to shifting marine habitat and species distributions in the North Pacific Ocean (IPCC, 2019). There has been a steady increase in North Pacific Ocean temperatures from 1950 to 2009 (Poloczanska et al. 2013; Holsman et al. 2018), and future temperatures are projected to increase 1.0–1.5 °C by 2050 relative to 2000 (Overland and Wang 2007). Of more imminent concern are marine heat waves in the Northeast Pacific Ocean, which have become a threat to FRS and other Pacific salmon species in recent years. Between 2013-2017, a warm water anomaly commonly referred to as "the Blob" created unobserved shifts in marine ecosystems along the Pacific coast of North America, altering marine animal distributions that affected predation and competition, created regions of low productivity and nutrients, and impacted several fisheries including salmon (Cavole et al. 2016). Concurrent to this anomaly was a strong El Niño event that further increased temperatures in late 2015 to early 2016, to the hottest observed throughout the 137 years of ocean temperature monitoring (Grant et al. 2019). During this event ocean surface temperatures were 3-5°C above seasonal averages, extending down to depths of 100 m (Bond et al. 2015; Ross and Robert 2018; Smale et al. 2019). Climate modeling has shown that "The Blob" marine heat wave cannot be explained without anthropogenic inputs, and extreme anomalies such as this will occur with increasing frequency in the coming decades under warming climatic conditions (Walsh et al. 2018), and more recent data continue to support these predictions. In 2019, another anomalous expanse of warm water developed along the Pacific Coast (National Oceanic and Atmospheric Administration [NOAA] Fisheries 2019[20]), and in 2020, a marine heatwave of about the same horizontal extent as the 2014 Blob encompassed much of southern California, the Southern California Bight, and into Mexican waters off Baja (NOAA Fisheries 2020[21]). The 2020 heatwave also lingered nearly a month longer into the fall and remained very strong in the far offshore region; however, neither the 2019 nor the 2020 heatwaves reached nearly as deep as The Blob, which warmed the water at least 100 meters deep in places (2019 and 2020 approximately 40 to 50 m).

The warm temperatures caused shifts in the distribution of zooplankton communities, driving lipid-poor southern copepod species northward while reducing numbers of lipid-rich subarctic and boreal copepods (Young and Galbraith 2018; Galbraith and Young 2019). Increases in temperature also increase the metabolic requirements of salmon, therefore food consumption must increase accordingly (Grant, MacDonald, and Winston 2019). Without a concurrent increase in prey quality or quantity, salmon growth and survival will decrease under warming conditions (Holsman et al. 2018). There is evidence showing decreases in body size and age in Sockeye and other Pacific Salmon species over the past several decades, which may be in part due to increasing metabolic and developmental demands as a consequence of warming temperatures (Gardner et al. 2011; Oke et al. 2020). Predation also can intensify in warmer ocean conditions, increasing mortality of salmon during these periods (Holsman et al. 2012), potentially exacerbating predation effects discussed in section 4.1.8.2. Warmer regional temperatures influence interactions between freshwater and marine ecosystems (Grant et al.

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[20] NOAA Fisheries. 2019. New Marine Heatwave Emerges off West Coast, Resembles “the Blob.”

[21] NOAA Fisheries. 2020. String of Marine Heatwaves Continues to Dominate Northeast Pacific.

2019). In general, warming and freshening of the upper ocean is projected during this century which will continue to reduce sea ice and increase ocean stratification (Bush and Lemmen 2019). Earlier snowmelt, increased precipitation, and melting of ice on land are some of the factors contributing to the freshening of the coastal Northeast Pacific surface waters (Bonsal et al. 2019; Greenan et al. 2019). Fresher and warmer surface waters increase ocean stratification, which limits the supply of nutrient rich deep ocean waters to the sunlit surface waters in the spring-to-fall growing season (Grant et al. 2019). This limits the nutrients available to support algal growth at the base of the salmon food web (Bush and Lemmen 2019).

The rapid increase in anthropogenic-derived CO_2 over the past two centuries has led to a decrease in ocean surface pH by 0.1 units through air–sea gas exchange, and approximately a 30% increase in hydrogen ion concentration. The ocean is projected to drop an additional 0.3–0.4 pH units by the end of this century (Mehrbach et al. 1973; Lueker, Dickson, and Keeling 2000; Caldeira and Wickett 2003; Caldeira et al. 2007; Feely et al. 2009; Guinotte and Fabry 2008). Caldeira and Wickett (2003) suggest that oceanic absorption of fossil-fuel-derived CO_2 may result in larger pH changes over the next several centuries than any inferred from the geological record of the past 300 million years, with the possible exception of those resulting from rare, extreme events. The rate and degree at which ocean acidification is occurring may exceed many marine organism's ability to adapt to changing environmental conditions (Hoegh-Guldberg and Bruno 2010), yet there is currently little research to date looking at the effects on salmon of elevated CO_2 in the marine environment (Williams et al. 2019). Ou et al. (2015) reported a variety of negative impacts (reductions in growth, yolk-to-tissue conversion, maximal O_2 uptake capacity, olfactory responses, anti-predator behaviour and anxiety) in Pink Salmon when fish were exposed to differing concentrations of CO_2 both in freshwater and in the early marine environment, and Williams et al. (2019) has indicated juvenile ocean-phase Coho Salmon are sensitive to neurobehavioral disruption induced by elevated CO_2 in the Puget Sound region. This would suggest FRS and other salmonids may share a sensitivity to rising CO_2 levels, yet there is currently insufficient evidence to quantify any DU-level impacts.

The impacts of shifting habitats has an immense amount of uncertainty for all FRS, particularly at the DU-level. FRS that migrate to their spawning grounds in summer months are experiencing more stress and greater depletion of their energy reserves, negatively impacting swim performance and survival, and the earlier onset of spring freshet and continued warming trends will likely pose more serious migratory challenges for earlier-timed FRS in the future (Tierney et al. 2009; Burt et al. 2011; Eliason et al. 2011; Sopinka et al. 2016; Grant et al. 2019). Unstable hydrological conditions in snow-dominated systems could also potentially inhibit conditions necessary to achieve successful spawning in some DUs in the interior Fraser basin and may have significant effects on the egg-smolt life stages. In addition to effects in freshwater, FRS in general spend approximately 3 years maturing in the ocean where they are exposed to many threats related to shifting marine conditions. Our limited knowledge of movements and behaviour in the open ocean, and our inability to monitor fish over great geographical areas greatly inhibits our ability to estimate the impacts on FRS, particularly at the DU-level. It is noted that there have been years of better-than-expected returns for several stocks in different systems along the coast in the same year as we've seen decreased returns for FRS, therefore declines in productivity are unlikely to be entirely due to changes in marine conditions.

The group agreed the population-level decline from the cumulative impacts (both in marine and freshwater) was more than 10%, and likely more than 30% in some DUs, in some years. It is unlikely that losses will be near the high end of the range (70%) on an annual basis from shifting habitats alone (i.e. modifications to ecosystems scored in section 4.1.7.3, freshwater temperature effects scored in section 4.1.11.3). Shifting habitats is, however, an exacerbating factor that compounds many of the threats identified throughout this document and is not anticipated to diminish in the near-future. Due to the great uncertainty quantifying these effects, an uncertainty range of medium-high (11-70%) was used for the level of impact, and all FRS are anticipated to be impacted similarly.

4.1.11.2. Droughts

This threat category involves periods in which rainfall falls below the normal range of variation, and loss of surface water resources (IUCN-CMP threat category 11.2).

Droughts are becoming more frequent in BC, creating migration barriers to salmon (i.e. low flows, high temperatures) and causing losses of incubating eggs and juveniles (Grant et al. 2019); however, the majority of FRS DUs are not anticipated to be impacted as they migrate through and spawn in areas with sufficient water depths to buffer the impacts from lost surface water resources (impacts related to flows and temperatures are scored in sections 4.1.7.3 and 4.1.11.3, respectively). In addition, juvenile FRS move into large lakes shortly after emergence where they remain for an extended period of time, buffering potential drought-related impacts. FRS expected to be impacted by drought are DU10 (Harrison (U/S)-L), DU16 (Quesnel-S), DU20 (Takla-Trembleur-EStu) and DU21 (Takla-Trembleur-EStu).

Droughts are not anticipated to be an annual occurrence yet they are expected to occur within the next three generations (2021-2032), therefore drought is a recurrent threat. Drought is also not anticipated to impact all FRS from any given DU; the group agreed that only a portion of FRS will be impacted as different cohorts exist simultaneously in freshwater and the ocean. Drought can cause access problems for DU10 (Harrison (U/S)-L); water is stored upstream of the spawning channel which restricts flows downstream, yet only the first portion of the run is generally impacted and likely exposes only a narrow portion (11-30%) of the stock to a low-level impact (1-10% decline). DU16 (Quesnel-S) lies within a highly prescribed area for agricultural water use and the DU is known to experience low flows and high temperatures in the summer, particularly in the Horsefly area. On a dominant year a broad portion (31-70%) of DU16 could be potentially exposed, and the group agreed these impacts were likely low (1-10%) as a direct result of drought conditions. For DU20 and DU21 (Takla-Trembleur-EStu/S), FRS must migrate through the lower Nechako River to reach the confluence to the Stuart River and are thus exposed to low flows from operations at Kenney Dam that may be exacerbated by drought. There are mitigations in place to maintain stable conditions in the lower reaches of the Nechako (see section 4.1.7.2), and if proper protocols are followed impacts will likely be negligible. As with DU16, on a dominant year DU20 and DU21 could have a broad portion (31-70%) of the population exposed to drought.

4.1.11.3. Temperature Extremes

This threat category includes periods in which temperatures exceed or go below the normal range of variation. This includes events such as heat waves, cold spells, temperature changes, and disappearance of glaciers/sea ice (IUCN-CMP threat category 11.3). Freshwater temperature impacts will be considered here, but marine temperature impacts will be considered in section 4.1.11.1 (IUCN-CMP threat category 11.1).

Temperature extremes are a threat to all FRS DUs covered in this RPA and these extremes are expected to increase in frequency in future years (Bush and Lemmen 2019). Salmon spawning migrations are energetically demanding even in optimal conditions, and these migration demands are exacerbated when temperatures fall outside the optimal range (Grant et al. 2019). High water temperatures increase energy consumption of Sockeye Salmon and migration failure can occur if energy reserves fall below a critical threshold (Rand and Hinch 1998; Rand et al. 2006), in addition to increasing the rate of development of pathogens causing physiological stress and disease (Gilhousen 1990; Fagerlund et al. 1995; Wagner et al. 2005; Martins et al.

2011). Female Sockeye also appear to be more vulnerable to the effects of high temperatures, having greater observed impacts when compared to males (Jeffries et al. 2012; Martins et al. 2012). Increasing air temperatures, reductions in snow packs, and receding glaciers are leading to river temperatures well above seasonal averages, and observations exceeding 18°C - 20°C in the summer months are becoming more common as far downstream as the lower Fraser River (Eliason et al. 2011; Martins et al. 2011; Macdonald et al. 2018; Grant et al. 2019). Temperatures above 18°C can lead to decreased adult swimming performance, and above 20°C can increase adult pre-spawn mortality and disease, reduce egg viability, and cause legacy effects that negatively impact juvenile condition (Tierney et al. 2009; Burt et al. 2011; Eliason et al. 2011; Sopinka et al. 2016). As such, all FRS are subject to potentially stressful water temperatures at the beginning of their freshwater migration, and many DUs that spawn in the upper reaches of the Fraser River basin will also encounter additional high temperatures in their natal systems. We note that exposure to moderate temperature increases relative to historical temperatures, over an extended period of time, may be just as harmful as higher temperatures over a short duration. This was not used as justification for the threat rankings presented here, however, future research is needed to investigate the cumulative effects of temperature exposure, and how these effects may impact individual FRS DUs.

Only a portion of each FRS DU will be exposed to freshwater temperature extremes in any given year, as multiple cohorts of fish exist in both the freshwater and marine environments. On a dominant year a potentially broad portion (31-70%) of most DUs would be exposed to temperature extremes, with the exception of DUs that do not have a dominant cycle line (i.e. DU10 Harrison (U/S)-L, DU17 Seton-L) in which a narrow portion (11-30%) would likely be exposed. DU20 (Takla-Trembleur-EStu) is most threatened by high temperatures, as fish from this DU have the earliest migration timing, the strongest reliance on the spring freshet, the most rapid migration rate, the longest migration distance, and do not hold in cold-water refugia during migration. While these fish often experience suboptimal temperatures in the lower reaches of the Fraser, FRS from DU20 experience the highest water temperatures once they enter the Nechako system. Mitigations are in place at Cheslatta Dam to maintain water temperatures below a threshold of 20 °C; however, these fish did not evolve to deal with the heavily modified flows and temperature currently present in the later stages of their migration. The group agreed the potential population-level declines resulting from extreme temperatures could exceed 30%, yet it is noted the impacts are both uncertain and unlikely to be at the high end of this range (70%). DU21 (Takla-Trembleur-S) must also migrate through the lower Nechako to reach the Stuart watershed, yet FRS from this DU are anticipated to be less impacted than DU20 due to their later migration timing and the buffering effects from the larger spawning streams and lake-headed systems.

All other FRS DUs are expected to be similarly impacted by temperature extremes, leading to medium level impacts (11-30%). As previously mentioned, a smaller proportion of FRS from DU10 and DU17 (11-30%) are expected to be impacted due to the absence of a dominant cycle line. The later timing for late-run DUs limits their exposure to high temperatures, yet a portion of the earlier migrants are likely impacted by high summer temperatures in August. There may also be slightly higher impacts within DU16 (Quesnel-S) when compared to these other DUs, particularly in the Horsefly area, where water temperatures have been known to exceed 22 °C (Macdonald et al. 2000); however, the DU-level impacts are still expected to be within the 11-30% decline from temperature extremes alone.

4.1.11.4. Storms and Flooding

This threat includes extreme precipitation and/or wind events. These events include thunderstorms, tropical storms, hurricanes, cyclones, tornados, hailstorms, ice storms or blizzards, dust storms, erosion of beaches during storms, changes in the flood regimes due to climate change (IUCN-CMP threat category 11.4).

Rain-dominated hydrographic systems in coastal BC are experiencing more extreme conditions, reflecting the greater variability in climate conditions (Grant et al. 2019). These conditions include greater variation between wet and dry conditions in the summer, and increased frequency and magnitude of storms and rainfall events (Pike et al. 2010). Mean annual air temperatures warmed by 1.4 °C between 1949 and 2006 across the Fraser River basin while total annual precipitation remained stable, despite a significant change in its type from snowfall to rainfall (Kang et al. 2016). This has impacted the accumulation and duration of seasonal snowpack by an approximate 19% decline in the contribution of snow to the hydrological regime (Choi et al. 2010; Kang et al. 2014; Picketts et al. 2017), resulting in a 10-day advance of the Fraser River's spring freshet (between 1949 and 2006) and subsequent reductions in summer flows (Kang et al. 2016). Despite decreasing snow accumulation at lower elevations, combinations of increased melt rates and more rainfall during the freshet period provide possible mechanisms for higher flood flows (Shrestha et al. 2015). Freshet flooding is influenced by annual winter accumulation of snowpack, paired with snowmelt runoff and specific temperature/rainfall conditions in the spring period (BC Ministry of Environment, Lands and Parks 1999). Some BC rivers are exhibiting more flash flooding, potentially leading to increased egg losses from scouring (Holtby and Healey 1986; Lisle 1989; Lapointe et al. 2000). Flash flooding may occur as a result of intense rainstorms, particularly affecting small to moderate sized streams throughout the province (BC Ministry of Environment, Lands and Parks 1999). Pest infestations (mountain pine beetle, spruce beetle) are another manifestation of climate change that have been shown to increase the frequency and intensity of flooding events through reduced interception, increased snowpack, reduced times of concentration and altered timing of snowmelt runoff (Winkler et al. 2008; EDI 2008; The Association of Professional Engineers and Geoscientists of British Columbia [APEGBC] 2016).

Storms and flooding within the Fraser basin are expected to impact most FRS DUs discussed in this RPA. Floods are not expected to be continuous events, rather there is the possibility of a significant flood occurring within the affected DUs in the next three generations (moderate timing). Floods will also not impact all FRS from an affected DU, as multiple cohorts exist in the freshwater and marine environments simultaneously. Further to this, flood events often occur in localized areas that may impact only a small proportion of a given DU.

DU20 (Takla-Trembleur-EStu) is expected to be one of the most threatened DUs from flooding, as these fish spawn in relatively shallow and unstable systems compared to other DUs. For example, in 2020 a flood within DU20 occurred with levels of discharge sufficient to mobilize spawning substrates and bury redds, impacting spawning habitat. Extreme rainfall events can also lead to downstream flows in the mainstem Fraser that are not passable by Sockeye (>8000m^3s^{-1}), leading to high levels of spawning migration mortality (Macdonald et al. 2000, 2010). This was also observed in 2020, where extreme rainfall halted migration until the rain subsided. There is considerable uncertainty in the proportion of the population that will be exposed, therefore an uncertainty range of 1-30% was chosen for the extent. The group felt that floods could lead to higher population-level declines than 10%, therefore an uncertainty range of 1-30% was chosen for the threat impacts. FRS from DU21 (Takla-Trembleur-S) are expected to have less severe impacts than DU20 due to the buffering effects of the larger sized spawning streams and lake-headed systems these fish use (1-10%).

DU10 (Harrison (U/S)-L) has a spawning channel that is intended to provide additional spawning habitat and protection from flooding, and only FRS spawning in Weaver Creek itself would be impacted in the event of a major flood. The group agreed that only a restricted portion of the population would be exposed (1-10%), with low impacts (1-10% population-level decline).

DU14 (North Barriere-ES) is a small DU that spawns within an area that has experienced significant impacts from fire and forestry, and a major flood event could have greater impacts than many other DUs. As with DU20, the group felt there could be potentially higher than 10% population-level declines in the event of a major flood, therefore an uncertainty range 1-30% was chosen.

FRS from DU2 (Bowron-ES), DU16 (Quesnel-S), DU22 (Taseko-ES) are expected to be similarly impacted by floods. Some systems within these DUs are known to flood but are unlikely to have more than low-level impacts at the DU-level (1-10%). Heavy rainfall events can contribute to migratory barriers in the mainstem Fraser from high flows, which are discussed in section 4.1.7.3.

DU17 (Seton-L) is not expected to be impacted by flooding; however, as noted in section 4.1.10.1, this DU is prone to landslides and ongoing sedimentation issues that threaten these fish. The area surrounding the DU is projected to see to a substantial increase in the frequency and intensity of extreme rainfall events with climate change (BGC 2018), and these rainfall events will likely contribute to continued slope destabilization and sediment inputs.

DU24 (Widgeon-RT) is not expected to be impacted by storms or floods, as these fish spawn in the lower reaches of the Pitt River in habitat under tidal influence.

Table 32. DFO threats assessment calculator results for impacts from Habitat Shifting and Alteration for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Habitat Shifting and Alteration

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU2 Bowron-ES	Known	Medium-High	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU10 Harrison (U/S)-L	Known	Medium-High	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU14 North Barriere-ES	Known	Medium-High	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Medium-High	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU17 Seton-L	Known	Medium-High	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Medium-High	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Medium-High	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Medium-High	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive
DU24 Widgeon-RT	Known	Medium-High	High	Medium-High (2)	Historical/Current/ Anticipatory	Continuous	Extensive

Table 33. DFO threats assessment calculator results for impacts from Drought for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Drought

Designatable Unit (DU)	**Likelihood of Occurrence**	**Level of Impact**	**Causal Certainty**	**Threat Risk**	**Threat Occurrence**	**Threat Frequency**	**Threat Extent**
DU10 Harrison (U/S)-L	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Recurrent	Narrow
DU16 Quesnel-S	Known	Low	Low	Low (4)	Historical/Current/ Anticipatory	Recurrent	Broad
DU20 Takla-Trem-EStu	Known	Negligible	Low	Negligible (4)	Historical/Current/ Anticipatory	Recurrent	Broad
DU21 Takla-Trem-S	Known	Negligible	Low	Negligible (4)	Historical/Current/ Anticipatory	Recurrent	Broad

Table 34. DFO threats assessment calculator results for impacts from Temperature Extremes for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Temperature Extremes

Designatable Unit (DU)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
DU2 Bowron-ES	Known	Medium	High	Medium (2)	Historical/Current/ Anticipatory	Continuous	Broad
DU10 Harrison (U/S)-L	Known	Medium	High	Medium (2)	Historical/Current/ Anticipatory	Continuous	Narrow
DU14 North Barriere-ES	Known	Medium	High	Medium (2)	Historical/Current/ Anticipatory	Continuous	Broad
DU16 Quesnel-S	Known	Medium	High	Medium (2)	Historical/Current/ Anticipatory	Continuous	Broad
DU17 Seton-L	Known	Medium	High	Medium (2)	Historical/Current/ Anticipatory	Continuous	Narrow
DU20 Takla-Trem-EStu	Known	High	High	High (2)	Historical/Current/ Anticipatory	Continuous	Broad
DU21 Takla-Trem-S	Known	Medium	High	Medium (2)	Historical/Current/ Anticipatory	Continuous	Broad
DU22 Taseko-ES	Known	Medium	High	Medium (2)	Historical/Current/ Anticipatory	Continuous	Broad
DU24 Widgeon-RT	Known	Medium	High	Medium (2)	Historical/Current/ Anticipatory	Continuous	Narrow/Broad

Table 35. DFO threats assessment calculator results for impacts from Storms and Flooding for all DUs. Note that categories are a slight modification of the COSEWIC Categories. Refer to the text for extensive comments on each threat and to DFO (2014b) for a detailed description of each factor level in the table.

Storms and Flooding

Designatable Unit (DU)	**Likelihood of Occurrence**	**Level of Impact**	**Causal Certainty**	**Threat Risk**	**Threat Occurrence**	**Threat Frequency**	**Threat Extent**
DU2 Bowron-ES	Known	Low-Medium	Low	Low-Medium (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU10 Harrison (U/S)-L	Known	Low-Medium	Low	Low-Medium (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU14 North Barriere-ES	Known	Low-Medium	Low	Low-Medium (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU16 Quesnel-S	Known	Low-Medium	Low	Low-Medium (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU20 Takla-Trem-EStu	Known	Low-Medium	Low	Low-Medium (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU21 Takla-Trem-S	Known	Low-Medium	Low	Low-Medium (4)	Historical/Current/ Anticipatory	Continuous	Extensive
DU22 Taseko-ES	Known	Low-Medium	Low	Low-Medium (4)	Historical/Current/ Anticipatory	Continuous	Extensive

4.1.12. Summary

This section has highlighted a multitude of anthropogenic-related threats that can lead to both direct and indirect declines in FRS. The results of the threats assessment suggest that all DUs considered in this RPA are expected to be at least a High level of risk over the next three generations (three generations is 10 years for DU24 Widgeon-RT, compared to 12 years for all lake-type DUs; High risk equates to a 31-70% population-level decline), and in some cases this risk could be Extreme (91-100% population-level decline). This is particularly true for the earliest-timed DUs that spawn above the Big Bar landslide (i.e. DU2 Bowron-ES; DU20 Takla-Trembleur-EStu; DU22 Taseko-ES), and for DUs that spawn in highly modified ecosystems such as in the Seton watershed (DU17 Seton-L). These DUs are currently at very low levels of abundance and productivity, and if many of the threats highlighted in this section are not reduced there is the potential for them to become extirpated within the next three generations (2021-2032). The more abundant Summer- and Late-run stocks such as DU10 Harrison (U/S)-L, DU16 (Quesnel-S), and DU21 (Takla-Trembleur-S) are not anticipated to face extirpation in the near future (i.e. next three generations), yet the declining trend in abundance observed over the last several decades suggests these populations are in serious peril, and are not recovering despite attempts in recent years at reducing levels of mortality. Table 36 provides a summary of threats to each DU and the overall threat ranking determined in the threats assessment workshop. Threats tables for each DU are provided in Appendix B.

Table 36. Overall threat ranking for FRS DUs assessed. Note this table displays the combined threat ranking of the multiple threat categories contained in each of the overarching major threat categories provided in the table.

COSEWIC Threat Category	**DU2 Bowron-ES**	**DU10 Harrison (U/S)-L**	**DU14 North Barriere-ES**	**DU16 Quesnel-S**	**DU17 Seton-L**	**DU20 Takla Trem-EStu**	**DU21 Takla Trem-S**	**DU22 Taseko-ES**	**DU24 Widgeon-RT**
Residential & commercial development	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Agriculture & aquaculture (Hatchery competition)	Low-Medium	Low-Medium	Low-Medium	Low-Medium	Low-Medium	Low-Medium	Low-Medium	Low-Medium	Low-Medium
Energy production & mining	N/A	N/A	N/A	Unknown	N/A	N/A	N/A	N/A	N/A
Transportation & service corridors	Negligible	Unknown	Negligible	Unknown	Unknown	Negligible	Negligible	Negligible	Unknown
Biological resource use (Fishing)	Medium	Medium-High	Medium-High	Medium-High	Medium-High	Low-Medium	Medium-High	Medium-High	Medium-High
Human intrusions & disturbance	Low	Negligible	Negligible	Low	Low	Low	Low	Low	Unknown
Natural systems modifications (Water management, ecosystems modifications)	Medium-High	Low-Medium	Medium	Medium	Medium	Medium-High	Medium	Medium-High	Low-Medium
Invasive & other problematic species & genes	Low-Medium	Low-Medium	Low-Medium	Low-Medium	Low-Medium	Low-Medium	Low-Medium	Low-Medium	Low-Medium
Pollution (From all sources and threats)	Low-Medium	Low-Medium	Low-Medium	Low-Medium	Low-Medium	Low-Medium	Low-Medium	Low-Medium	Low-Medium
Geological events (Landslides)	Medium-High	Negligible	N/A	Medium	High	Extreme	Medium	Medium-High	N/A
Climate change & severe weather (Shifting habitats)	Medium-High	Medium-High	Medium-High	High	Medium-High	High	High	Medium-High	Medium-High
OVERALL THREAT RANKING	High-Extreme	High	High-Extreme	High	High-Extreme	Extreme	High	High-Extreme	High

4.2. ELEMENT 9: ACTIVITIES MOST LIKELY TO THREATEN THE HABITAT PROPERTIES IDENTIFIED IN ELEMENTS 4-5

The majority of Threats identified in Element 8 may impact habitat properties from Elements 4-5. The pathways have been described throughout Element 8 and the primary threats associated with each DU are highlighted in section 4.1.12.

4.3. ELEMENT 10: NATURAL FACTORS THAT WILL LIMIT SURVIVAL AND RECOVERY

4.3.1. Physiological and behavioural factors

Temperature is one of the most important environmental influences on salmonid biology (Carter 2005), and is strongly tied to the evolutionary histories of salmonids in the Northeast Pacific and their historical distributions (Brannon et al. 2004). Water temperature can affect salmonids at all life history stages, having both direct and indirect effects on the health of individual fish through a variety of mechanisms (Dunham et al. 2001; Richter and Kolmes 2005) including growth and feeding rates, metabolism, development of embryos and alevins, timing of life history events such as upstream migration, spawning, freshwater rearing, and seaward migration, and the availability of food (Carter 2005). Temperature effects on migrating adult Sockeye have been well documented in the Fraser River watershed (Rand et al. 2006; Crossin et al. 2008; Martins et al. 2011; Middleton et al. 2018), and differences in thermal tolerances have been reported between populations (Eliason et al. 2011). In general, fish with more challenging migratory environments have greater aerobic scope, larger hearts, and better coronary supply, and thermal optima for aerobic, cardiac, and heart rate scopes are also consistent with the range of historic river temperatures for each population. Of the populations sampled, Chilko Sockeye (DU3/4 Chilko ES/S; not covered in RPA) were shown to have the greatest ability to maintain cardiorespiratory performance at higher temperatures, followed by Gates (DU1 Anderson-Seton-ES; not covered in RPA), Early Stuart (DU20), Quesnel (DU16) Nechako, (DU7/8 Fraser-Francois-S/Nadina-Francois-ES); not covered in RPA), and Weaver Sockeye (DU10 Harrison (U/S)-L). The greater cardiorespiratory ability in Gates and Chilko Sockeye (both considered Not at Risk under COSEWIC) may be a contributing factor for relatively stable returns compared to DUs considered in this RPA. FRS from DU10 were shown to have the lowest cardiorespiratory ability at high temperatures which is particularly problematic due to high temperatures observed in the lower Fraser River in some years (see section 4.1.11.3), paired with an advance in migration timing observed in late-run FRS that has increased their exposure to potentially lethal conditions (Hague et al. 2011).

Changes in migratory behavior has been observed since the mid 1990s for a variety of late-run FRS populations. In 1995, a proportion of individuals from late-run populations (e.g. DU6 Cultus-L, DU9 Harrison (D/S)-L, DU10 Harrison (U/S)-L, DU17 Seton-L, DU18 Shuswap Complex-L) arrived off-shore near the mouth of the Fraser River at the normal time, yet entered the river 3 weeks earlier than anticipated (Hinch et al. 2012). Since this observed shift in migration timing a proportion of FRS have consistently entered the river earlier than expected, in some cases leading to extremely high pre-spawn mortality. Total freshwater mortality (excluding harvest) ranged from 40 to 95% for most late-timed DUs since the early migration phenomenon began, compared to estimates of less than 20% prior to the phenomenon occurring (Hinch et al. 2012). DU10 (Harrison (U/S)-L) and DU17 (Seton-L) are the only two late-timed DUs considered in this RPA, and the shift in migration timing has been particularly problematic for DU10. Between 1995 and 2010, DU10 experienced >50% mortality and in several years >80% mortality, while DU17 (and other late-timed DUs) experienced >50% en route mortality in over half of these same brood years (Hinch et al. 2012). This advance in timing is still being observed and has occurred for reasons that are yet unknown (DFO 2020b).

Straying is a natural life history trait of Pacific salmon, and is a critical evolutionary feature of salmonid biology that buffers against spatial and temporal variation in habitat quality, and allows colonization of new habitats (Keefer and Caudill 2014). However, the demographic and ecological effects of strays on small populations are not always positive. For example, strays may compete with local fish for redd sites and mates but fail to reproduce, lowering overall productivity, and those that successfully breed with the recipient population may dilute locally-adapted traits through introgression (Keefer and Caudill 2014). Even low (~1 %) rates of straying from large donor populations can numerically swamp small recipient populations (Keefer and Caudill 2014). Following the Big Bar landslide, there is concern there may be potential straying effects for FRS that are unable to pass the Big Bar landslide. Fish unable to migrate upstream of the slide may disperse downstream into other systems locations such as the Bridge, Nahatlatch, and Stein, where adult fish in poor health condition have been observed (C. Parken 2019 pers. comm.). If the Big Bar landslide poses migratory challenges in future years, the straying of fish from upstream DUs into other systems may be a future source of genetic introgression that could lead to reduced fitness or survival.

4.3.2. Predation

FRS are faced with predatory interactions throughout all life stages and in all habitats. The threat of predation begins as an egg and carries onto the entire juvenile freshwater life stage, with sources including a variety of opportunistic fish, mammal, avian, and invertebrate species (Christensen and Trites 2011). Predation is a natural limiting factor for FRS and other fish. Pacific Salmon have successfully dealt with predation through evolutionary time by developing a complicated life history that includes moving between ranges of habitats varying in the risks they represent (Christensen and Trites 2011). Sockeye Salmon have historically overwhelmed predators through large synchronous returns to localized spawning areas, with a subsequent large pulse of eggs, alevins, fry, smolts, sub-adults and adults moving in concert through a string of ecosystems, and saturating predators. This results in declining predation mortality rates as Sockeye abundance increases (Christensen and Trites 2011). However, at low abundances such as seen in recent years for many of the Threatened or Endangered FRS DUs, the impacts from predation may be depensatory and significant (i.e. at low densities predatory effects are greater). For the smolt life-stage in particular, predation can be high as predators aggregate to exploit smolts in rivers and estuaries (Zimmerman and Ward 1999; Petersen 2001; Furey et al. 2016; Furey and Hinch 2017), influencing location-specific mortality (Schreck et al. 2006; Evans et al. 2012; Osterback et al. 2013; in Furey et al. 2021). Some predatory interactions (i.e. pinniped predation) are influenced or exacerbated by anthropogenic activities, and were discussed in the threats assessment (see section 4.1.8.2).

As part of the Cohen Commission of Inquiry into the Decline of Sockeye Salmon, Christensen and Trites (2011) investigated interactions with many potential predators of FRS, yet conclude that while there are many predators that likely impact FRS, there is no “smoking gun” in terms of predatory effects leading to declines. There are many factors that confound the impacts of predators. There have been major shifts in the marine environment that has changed invertebrate and fish community structure and distribution, potentially impacting FRS on multiple trophic levels including increased predation and competition for resources (see section 4.1.11.1). There are also cumulative effects from the threats identified in Element 8 that may lead to increased predation rates. For example, warm water temperatures can lead to a higher prevalence of disease, which in turn can change the behaviour of salmon such that they become more susceptible to predation. There is considerable uncertainty surrounding these dynamics, in addition to ecosystem-level information about predators of FRS (e.g. abundance, diets, trends, distributions), and is a noted knowledge gap (Appendix C). Table 37 displays a list of potential predators of FRS; however, this list should not be considered exhaustive. For a detailed summary of these predators and their potential interactions with FRS, refer to Christensen and Trites (2011).

Table 37. Predators likely encountered by FRS. Modified from Christensen and Trites (2011).

Predator Group	Common name	Scientific name
Freshwater Fish	Bull trout	*Salvelinus confluentus*
	Burbot	*Lota Lota*
	Chinook Salmon	*Oncorhyncus tshawytscha*
	Coho Salmon	*Oncorhyncus kisutch*
	Cutthroat Trout	*Oncorhyncus clarkii clarkii*
	Dolly Varden	*Salvelinus malma*
	Lake Trout	*Salvelinus namaycush*
	Largemouth Bass	*Micropterus salmoides*
	Northern Pikeminnow	*Ptychocheilus oregonensis*
	Rainbow Trout/Steelhead	*Oncorhyncus mykiss*
	River Lamprey	*Lampetra ayresi*
	Sculpin Spp.	*Cottus spp.*
	Smallmouth Bass	*Micropterus dolomieu*
	Yellow Perch	*Perca flavescens*
Marine Fish	Arctic Lamprey	*Lampetra camtschatica*
	Blue Shark	*Prionace glauca*
	Longnose Lancetfish	*Alepisaurus ferox*
	North Pacific Daggertooth	*Anotopterus nikparini*
	Pacific Hake	*Merluccius productus*
	Pacific Herring	*Clupea harengus pallasi*
	Pacific Lamprey	*Lampetra tridentata*
	Pacific Mackerel	*Scomber japanicus*
	Pacific Sleeper Shark	*Somniosus pacificus*
	Sablefish	*Anoplopoma fimbria*
	Salmon Shark	*Lamna diprosis*
	Spiny Dogfish	*Squalus acanthias*
Avian	Double Crested Cormorant	*Phalacrororax auritus*
	Common Merganser	*Mergus merganser*
	Gulls	*Larus spp.*
	Caspian Tern	*Hydroprogne caspia*
	Bald Eagle	*Haliaeetus leucocephalus*
	Osprey	*Pandion haliaetus*
Mammals	Brown bear	*Ursus arctos*
	Black bear	*Ursus americanus*
	California Sea Lion	*Zalophus californianus*
	Coyote	*Canis latrans*
	Dall‘s Porpoise	*Phocoenoides dalli*
	Harbour Seal	*Phocavitulina richardsi*
	Harbour Porpoise	*Phocoena phocoena*
	Humpback Whale	*Megaptera novaeangliae*

Predator Group	Common name	Scientific name
	Killer Whale (Residents)	*Orcinus orca*
	Mink	*Mustela vison*
	Northern Fur Seal	*Callorhinus ursinus*
	Pacific White-Sided Dolphin	*Lagenorhynchus obliquidens*
	Steller Sea Lion	*Eumetopias jubatus*
	River Otter	*Lontra canadensis*
	Wolf	*Canis lupus*
Invertebrate	Humboldt Squid	*Dosidicus gigas*

4.3.3. Competition

FRS compete with a multitude of co-occurring species in the freshwater and marine environments. Due to their relatively unique life history and behaviour compared to other Pacific Salmon, FRS in freshwater are not faced with high levels of interspecific competition with other salmon species. Kokanee, the non-anadromous form of Sockeye Salmon, is likely the main freshwater competitor of FRS. During their juvenile stage Sockeye are similar ecologically to Kokanee, with a high degree of habitat overlap and feeding behaviour that indicates the possibility of food competition (Wood et al 1999). There are large abundances of Kokanee in the Stuart-Takla (DU20 Takla-Trembleur-EStu and DU21 Takla-Trembleur-S) and Quesnel (DU16 Quesnel-S) systems, with multi-age cohorts that could represent a significant source of competition for rearing juveniles. In systems such as these, we note that lake fertilization, an enhancement tool used for FRS (discussed in section 6.1.9), may benefit Kokanee populations to a point where increased and negative competitive interactions occur with FRS. There is currently insufficient evidence to quantify the level of competition between Sockeye and Kokanee at the DU-level for FRS and is highlighted as a source of uncertainty that requires future research (Appendix C). There are a variety of other co-occurring freshwater species that compete with FRS, including many of the predators highlighted in the above section, yet there is currently no evidence to suggest these competitive interactions are limiting recovery. In freshwater FRS are faced with intraspecific competition for spawning and rearing habitat, however yet at current abundances this is not considered to be a limiting factor for the DUs considered here.

There have been considerable shifts in marine invertebrate and fish community structure due to warming ocean temperatures and marine heatwaves (see section 4.1.11.1), which has consequently led to shifts in Sockeye diet and likely competitive dynamics. For example, lipid-poor southern copepod species have been observed to be moving northward while lipid-rich subarctic and boreal copepods have been observed in reduced numbers (Young and Galbraith 2018; Galbraith and Young 2019), and energetically superior planktonic species such as hyperiids and euphausiids are being seen in reduced numbers in Sockeye diets while juvenile squid, forage fish, and other lower-energy prey have become more prevalent (Karpenko et al. 2007). There is also evidence that jellyfish populations in coastal ecosystems may be on the rise (Brotz et al. 2012; Purcell 2012), and it has been suggested pose a form of indirect exploitative competition to Pacific salmon. Jellyfish also have several characteristics that place them in an influential position to restructure energy flow through pelagic food webs: high rates of growth and reproduction, broad planktivorous diets, and apparently few predators as adults (Condon et al. 2012; Robinson et al. 2014). Increases in temperature also increase the metabolic requirements of salmon, therefore food consumption must increase accordingly (Grant et al. 2019). Without a concurrent increase in prey quality or quantity, salmon growth and survival will decrease under warming conditions (Holsman et al. 2018). There is evidence showing decreases in body size and age in Sockeye and other Pacific Salmon species over the past several decades, which may be in part due to increasing metabolic and developmental demands as a consequence of warming temperatures (Gardner et al. 2011; Oke et al. 2020). The decrease in body size and age has also been suggested to be influenced by competitive interactions between Sockeye and high abundances of hatchery fish, particularly Pink Salmon (see section 4.1.2.3; Ruggerone and Connors 2015; Ruggerone and Irvine 2018; Connors et al. 2020).

4.4. ELEMENT 11: DISCUSSION OF THE POTENTIAL ECOLOGICAL IMPACTS OF THREATS FROM ELEMENT 8 TO THE TARGET SPECIES AND OTHER CO-OCCURRING SPECIES, CURRENT MONITORING EFFORTS, AND KNOWLEDGE GAPS

Many of the threats identified in Element 8 are likely to also negatively impact co-occurring predators, competitors, and prey of FRS. Predators of FRS have likely been negatively impacted by continued reductions in Sockeye abundance over the last several decades, yet there are instances where threats may actually improve the success of a predator targeting FRS. For example, FRS infected with sea lice or other pathogens or exposed to a variety of environmental pollutants may have visual or swimming impairment, reduced stamina, and occupy peripheral positions of schooling fish that lead to potentially higher levels of predation. Introduced non-native species such as spiny-ray fishes in the lower Fraser River may also benefit from increased temperature regimes in freshwater, as they have physiological tolerances to high temperatures and can outcompete native species. Competitors will generally benefit from lower abundances of FRS, yet if they share similar habitat or prey requirements then they will also likely be negatively impacted by the threats identified in Element 8. In some instances, competitors may be more able to adapt to these threats, potentially providing a competitive advantage over FRS. Prey of FRS would also generally benefit from reductions in Sockeye abundance, yet many preferred prey species of Sockeye have been observed in reduced numbers, particularly in the marine environment, when compared to previous years suggesting they are also being negatively impacted.

Most of the threats that would impact habitat features would also impact many of the co-occurring species. For example, any terrestrial predator would be impacted by changes to the watershed catchment such as decreases in forests or increased urbanization. Trees and riparian vegetation are also directly impacted as they are the habitat features that are often destroyed. Changes to freshwater flow through dams and irrigation will affect all aquatic species, most in a negative way. In addition to habitat destruction, riparian vegetation can be impacted by declining salmon populations through a reduction in nutrient inputs from carcases (Hocking and Reynolds 2011). Salmon deliver an annual flux of nutrient subsidies from the marine to the terrestrial environment that can have strong and unforeseen ecological impacts (Wagner and Reynolds 2019). Salmon carcasses are transferred to adjacent terrestrial habitat by predators (e.g. bears, wolves) and through flooding and hyporheic flow (Hilderbrand et al. 1999; Gende et al. 2002; Buxton et al. 2015a), enhancing primary production, favoring plant growth and structural complexity (Helfield and Naiman 2001; Mathewson et al. 2003; Reimchen and Fox 2013), and influencing the diversity of understory vegetation (Hocking and Reynolds 2011; Hurteau et al. 2016; Wagner and Reynolds 2019). The impact of reduced nutrients will vary between each watershed, yet it is likely to have a larger effect in smaller, and more nutrient poor watersheds (Hocking and Reynolds 2011).

There are many knowledge gaps surrounding the threats identified in Element 8 and their ecological impacts. Appendix C lists knowledge gaps and sources of uncertainty identified throughout this RPA process, yet it is noted this list is not exhaustive.

5. ELEMENT 14: PROVIDE ADVICE ON THE DEGREE TO WHICH SUPPLY OF SUITABLE HABITAT MEETS THE DEMANDS OF THE SPECIES BOTH AT PRESENT AND WHEN THE SPECIES REACHES THE POTENTIAL RECOVERY TARGET(S) IDENTIFIED IN ELEMENT 12.

RPAs aim to provide advice on the status of habitat *supply* and *demand,* and to inform discussion about whether habitat availability is currently limiting population growth, both at present, and when the species reaches its recovery target(s) (DFO 2014c). *Supply* in this context refers to the amount of different habitat types known to exist, and how much each habitat type can be expected to support, should the population of the species saturate the habitat. *Demand* refers to habitat usage by the species and is estimated from the population size and densities that can be reached in different types of habitat.

Previous works have described freshwater migratory, rearing, and spawning habitat for FRS. This information is largely unavailable for the marine environment due to challenges monitoring vast and unconstrained geographical areas. We note that due to the high abundance of hatchery salmon in the Pacific Ocean (particularly Pink Salmon, see section 4.1.2.3), the supply of suitable habitat in the marine environment may have been reduced through time due to increased competition for resources, yet there is currently little evidence to quantify this. Migratory habitat estimates for FRS are based on the distance travelled in-stream during their spawning migration, and is represented by linear km. Spawning habitat is estimated for each DU using a combination of data from the government-maintained Fisheries Information Summary System (FISS) and expert/local knowledge (Nelitz et al. 2011; COSEWIC 2017a), and is reported as an index of area of occupancy (IAO; see section 2.2.1). The majority of DUs considered in this RPA rear in a large nursery lake for approximately one year, and much of this time is spent foraging in the pelagic zone of the lake. As such, rearing habitat for these DUs includes the total geographic area of their respective nursery lake. The exception to this is DU24 (Widgeon-RT), the only ocean-type variant considered in this RPA, which rears in the lower Fraser River prior to migrating out into the Strait of Georgia (see section 2.1 for discussion of FRS life history). Much of the available information on habitat use for ocean-type FRS is from Harrison ocean-type Sockeye (DU23 Harrison-RT), which are much more abundant. Our knowledge of habitat use and supply is therefore extremely limited for DU24, and is a notable knowledge gap (Appendix C).

It is noted there are inherent challenges in reliably estimating the supply and quality of these habitats. For example, it may be possible to define the extent of potential spawning reaches but it is more difficult to define actual quality of spawning substrates (Dan Selbie, DFO pers. comm.; Nelitz et al. 2011). Seasonal fluctuations in environmental and hydrologic conditions may also change the availability, quantity, and quality of all habitat types. For example, habitat access or availability may be impacted by low or high flows, water temperatures, landslides, sedimentation, anchor or frazil ice formation, and a variety of other physical, chemical, biological, or climate-driven threats and limiting factors identified in Elements 8 and 10. We highlight this as a source of uncertainty, yet it would require considerable effort and funding to investigate, monitor, and quantify the aforementioned habitat metrics within large geographic areas of the Fraser River watershed. Table 38 displays available habitat metrics for each DU, where available.

All the DUs considered in this RPA have either declined at rates greater than 30% (Threatened; DU10 Harrison (U/S)-L, DU14 North Barriere-ES, DU16 Quesnel-S) or 50% (Endangered; DU2 Bowron-ES, DU17 Seton-L, DU20 Takla-Trembleur-EStu, DU21 Takla-Trembleur-S, DU22 Taseko-ES) within the past three generations (2009-2020), have population sizes of less than 1000 individuals (DU17, DU22, DU24 Widgeon-RT), or have a combination of these factors

(COSEWIC 2017a; DFO 2020a). In most cases the declines over the last three generations are not from levels in which habitat saturation was a concern. Ricker (1987) indicated nearly four decades ago that other than the largest producing stocks such as Chilko (DU3/4), Quesnel (DU16), and Shuswap (DU18/19) lakes, most FRS DUs in the BC interior had underutilized rearing habitat capacity in all observed cycle years, with escapements substantially lower than those prior to the 20th century. Work by Shortreed et al. (2001) indicated that rearing capacity may have been reached or exceeded in only two nursery lakes used by FRS considered here, DU14 (North Barriere-ES) and DU16 (Quesnel-S). However, the escapement data used in this study was collected between 1977 and 2000, a period in which returns were much higher than current levels (see section 2.2.2 for abundance plots).

It is still generally considered that the current available habitat can support and has historically supported much higher abundances of Sockeye for the DUs considered in this RPA. As such, **habitat supply is not considered to be a factor limiting these DUs from reaching their assigned recovery targets.** We note one exception to this statement for DU24 Widgeon-RT; this is a small (<1000 individuals) and unique ocean-type population that was assigned a status of Threatened by COSEWIC due to its low abundance and susceptibility to anthropogenic threats, rather than a decline in abundance as seen with many other DUs. Habitat supply within DU24 is limited in that it will not support higher numbers of fish observed throughout the recorded time-series, but habitat supply is not considered to be a limiting factor for this DU.

Further discussion of DU-specific spawning and rearing habitat, and potential restoration and enhancement activities can be found in section 6.1.9.

Table 38. Habitat characteristics for FRS DUs considered in this RPA. Nursery lake habitat metrics reported in (Shortreed et al. 2001).

Designatable Unit (DU)	Migration Distance	IAO	Nursery Lake	Surface Area	Mean Depth
DU2 Bowron-ES	870 km	16 km^2	Bowron Lake	10 km^2	16 m
DU10 Harrison (U/S)-L	100 km	4 km^2	Harrison Lake	220 km^2	151 m
DU14 North Barriere-ES	450 km	20 km^2	North Barriere Lake	5.2 km^2	35 m
DU16 Quesnel-S	640 km	352 km^2	Quesnel Lake	270 km^2	158 m
DU17 Seton-L	320 km	20 km^2	Seton Lake	24 km^2	85 m
DU21 Takla-Trembleur-EStu	1000 km	428 km^2	Takla Lake Trembleur Lake Stuart Lake*	246 km^2 116 km^2 359 km^2	107 m 40 m 20 m
DU21 Takla-Trembleur-S	870 km	164 km^2			
DU22 Taseko-ES	500 km	24 km^2	Taseko Lake	31 km^2	43 m
DU24 Widgeon-RT	25 km	4 km^2	N/A	N/A	N/A

* FRS from both DU20 and DU21 use habitat in Takla and Trembleur lakes, while FRS from DU21 also use Stuart Lake.

6. SCENARIOS FOR MITIGATION OF THREATS AND ALTERNATIVES TO ACTIVITIES

6.1. ELEMENT 16: INVENTORY OF FEASIBLE MITIGATION MEASURES AND REASONABLE ALTERNATIVES TO THE ACTIVITIES THAT ARE THREATS TO THE SPECIES AND ITS HABITAT

Element 8 identified a multitude of threats that negatively impact FRS at all life stages, yet many of these threats are complex and interrelated through a variety of physical, biological and chemical processes that occur over large geographical areas. Considerable knowledge gaps and sources of uncertainty are associated with many of these threats (Appendix C), making it extremely challenging to link and quantify changes in abundance to specific mitigation activities, particularly at the DU level. This section provides broad descriptions of activities and techniques that could generally be employed to mitigate the threats identified in Element 8, yet we do not attempt to prioritize specific mitigation activities due to the high level of uncertainty associated with many of these threats. Much of the information presented in this section is highlighted in other recent Pacific Salmon RPAs (Interior Fraser Coho, Fraser Chinook) and is highly relevant to all the imperilled Pacific Salmon species.

6.1.1. Development

The lower Fraser River is the most densely populated area in BC and contains the highest concentration of housing and urban areas, commercial and industrial developments, and tourism and recreation activities. There is limited available habitat available for further developments of these types adjacent to the lower Fraser River, its tributaries, and estuary, yet given increasing population growth in the Greater Vancouver area there will likely be increasing demands for expansion in the future. Identifying critical areas for FRS in the lower Fraser will be important to mitigate further degradation to the limited available habitat, which will benefit not only FRS but other salmonids that rear in the lower Fraser River. It was noted in section 3.1 that lake-type FRS (all DUs except DU24 Widgeon-RT) rapidly migrate this area and would likely not be greatly impacted, yet ocean-type FRS (DU23 Harrison-RT, DU24) are thought to rear for an extended period of time in the lower Fraser River before moving into the Strait of Georgia and would therefore benefit the most from habitat preservation in these areas. There have been concerns raised regarding the effectiveness of current frameworks for identifying critical habitat. Sharpe et al. (2019) indicate the habitat characteristics used in Canadian provincial and federal environmental risk assessments for identifying important salmon habitat are often oversimplifications of dynamic habitat mosaics, and that more intensive field studies are needed to identify regions where developments may pose particularly high risks. The authors do, however, emphasize that even with extensive research there is still a large degree of uncertainty associated with predicting the abundance of salmon across space and time.

Coker et al. (Coker et al. 2010) developed a broad guidance document to accompany Central and Arctic Region RPAs but it is relevant to all fish-bearing systems. This document comprehensively detailed linkages between works and activities and their “pathways of effects”, as well as mitigation strategies to break those pathways. These are specific mitigation measures that can be undertaken by those working in and around water. When development activities do not directly occur in fish habitat, the potential larger-scale implications on fish productivity are often not considered. Planning for development within all sectors needs to consider the cumulative hydrological effects within watersheds and the existing state of a watershed’s hydrological health, as which is inextricably linked to salmon survival and productivity (Hartman and Brown 1988; Tschaplinski and Pike 2017b). There are a number of legislated Acts and their associated guidance policies and documents that detail the regulations and best practices for works or activities which impact fish. These frameworks include but are not exclusive to: the *Provincial Riparian Area Regulations* under the *Riparian Areas Protection Act*, the *Forest and Range Practices Act*, the *Mines Act*, the *Water Sustainability Act,* the *Federal Fisheries Act* and the *Fisheries Protection Policy Statement*. There is also the *Environmental Assessment Act*[22] which provides a framework for reviewing major projects to assess their potential impacts and to ensure that the projects meet the goals of environmental, economic and social sustainability.

The aforementioned Acts, policies, and guidance documents recognize the link between activities and habitat threats and provide the regulatory framework for reducing those threats; however, cooperation within multijurisdictional regulation frameworks, policy interpretation, planning, monitoring and enforcement are all areas which require support and funding. In addition, they are only as useful as they are enforceable. In many cases mitigation is associated with extra costs. Significant gaps have been identified in models which use professional reliance or self-declared development plans with habitat impacts to ensure compliance with regulations (Office of the Ombudsperson 2014; Haddock 2018). These planning and monitoring methods create a conflict of interest between profit and fish protection, which has detrimental effects on mitigation enforcement (Haddock 2018). Adequate resourcing to assist with third party planning, monitoring and enforcement of regulations is required. In addition to enforcement and third-party planning, mandatory financial safety-nets for unforeseen problems (e.g. spills or breaches) would be beneficial. A legal and policy framework that is consistently applied at the municipal, regional district, provincial, federal, and First Nations levels would help to ensure the protection of salmon.

6.1.2. Agriculture and aquaculture

Several threats associated with agriculture were identified in Element 8, including loss and degradation of riparian habitat, livestock entering streams, water extraction, and pollution (water extraction and pollution mitigation discussed in sections 4.1.7.2 and 4.1.9, respectively). All FRS transit the lower Fraser River twice in their lifetime and are exposed to high concentrations of agricultural developments in the Fraser Valley Regional District (Abbotsford, Chilliwack, Hope, Kent, Mission, Harrison Hot Springs). Approximately 67% of land in these regions is actively farmed or supporting farming, yet the remaining land (≈18%) in these areas is comprised of relatively small parcels which provide limited opportunity for further agricultural development (BC Ministry of Agriculture 2016). As a result, intensification or conversion of existing land is the most likely threat to FRS in the future.

Mitigating the impacts of new agricultural development and land conversion needs to consider both the direct physical impacts from those activities such as loss or degradation of habitat, and the larger scale implications such as impacts on stream hydrologic function, runoff dynamics, and pollution. In addition to the acts listed above in section 6.1.1, there are additional pieces of legislation that aim to reduce the impacts from agriculture, and include: the *Environmental Management Act, Public Health Act*, and *Integrated Pest Management Act*. The province also provides a number of stakeholder resources like the *Riparian Areas Protection Regulation*[23] *(RAPR)* that is enacted under the *Riparian Areas Protection Act* and the *Farmland-Riparian Interface Stewardship program*[24]*(FRISP)*. The RAPR calls on local governments in BC to protect riparian areas during residential, commercial and industrial development by ensuring that a qualified environmental professional conducts a science-based assessment of proposed

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[22] Environmental Assessment Act.

[23] Riparian Areas Protection Regulation (RAPR)- Riparian Areas Protection Act.

[24] Farmland-Riparian Interface Stewardship program (FRISP)- BC Cattleman's Association.

activities. The FRISP delivered by the BC Cattleman's Association (BCCA), is designed to help provincial agriculture producers to protect and enhance water quality, to protect and enhance riparian vegetation, and prevent and mitigate agricultural impacts on streams and lakes[25]. FRISP provides a wide range of services for riparian and fish habitat, waste management and restoration projects in the form of technical information, training, advice, project prescriptions, cost estimates and project support and mediation services for invested stakeholders. The Environmental Farm Plan[26] also aims to support agricultural operations to minimize environmental risks and provide on-site assessments and guidance for factors such as riparian integrity, irrigation and drainage, water quality, air quality and emissions control, and on-farm materials storage. These programs should be utilized when possible to ensure the protection of FRS habitat.

DU16 (Quesnel-S) is the only DU expected to be impacted from cattle ranching as it lies within a heavily prescribed area for beef cattle production, particularly in the area surrounding the Horsefly River (can be greater then 50% of return to DU16), and low water conditions allow cattle to enter streams and potentially trample redds or critical habitat. In general, fencing can be used to prevent access to streams, yet cattle often range over large geographic areas where monitoring and enforcement are lacking. Charnley et al. (2018) summarize strategies used to reduce grazing impacts, which include permanently fencing stream corridors containing critical fish habitat, increasing controls on timing and use of riparian pastures throughout the grazing season, develop alternate water sources in upland areas to keep livestock away from riparian areas, shorten season of use on allotments, provide nutritional supplements in uplands (e.g., salt, mineral and mineral blocks to drive livestock away from streams), and temporarily fence redds during spawning season. These approaches are generally site or area specific and will depend on cooperation with land owners, therefore it will be important to build between trust between ranchers, resource managers, and regulating agencies.

The footprint of open net-pen aquaculture was anticipated to have negligible impacts on FRS, yet disease and pollution associated with net-pen aquaculture has become an area of significant debate in recent years (mitigating these impacts discussed in section 4.1.2.3 and 4.1.9.3, respectively). The recent announcement by DFO Minister Bernadette Jordan to phase out net-pen aquaculture in the Discovery Islands, a major migratory corridor of FRS, will likely alleviate some of these concerns in coming years. This announcement states no new fish of any size may be introduced into Discovery Islands aquaculture operations, and all of these operations free of fish by June 30th, 2022, but that existing fish at the sites can complete their growth-cycle and be harvested[27]. Further to this, there is a federal commitment to transition to closed-containment aquaculture by 2025, which will further reduce the footprint of aquaculture in other areas of coastal BC.

The main threat to FRS from aquaculture is competition with hatchery fish, particularly with Pink and Chum salmon which are produced at high levels in distant regions (e.g. Russia, Japan, Alaska). There has been considerable work done that suggests there are negative consequences to high levels of hatchery production (see section 4.1.2.3), yet hatchery production continues to increase in some regions. Connors et al. (2020) highlight the importance of international cooperation to consider, and potentially constrain the number of hatchery salmon released into the ocean in an increasingly uncertain future. While we do not

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[25] Riparian Area Resources.

[26] Environmental Farm Plan.

[27] Government of Canada News Release.

have control over hatchery production in other regions, we can continue to support the understanding of these competitive interactions through continued research.

6.1.3. Fishing impacts

Declining trends in FRS abundance since the 1980s has led to significant changes in targeted fisheries, and exploitation rates have been greatly reduced for all DUs. FRS fisheries are currently managed using in-season information so that fisheries can be reduced or halted if escapement goals are not expected to be met. FRS fishing openings are subject to in-season reductions based on poor in-river migration conditions, such as elevated water temperatures, or discharge levels for Early Stuart, Early Summer and Summer MUs (Macdonald et al. 2010; DFO 2017). Adjustments for anticipated poor upstream migration success for Late Run MU is tied to earlier in-river entry dates. The earliest-timed stocks are provided some protection from fishing in most years, particularly for DU20 (Takla-Trembleur-EStu), in which there is a 3–4-week closure to fishing during their migration. In years where this window is extended to 4 weeks there is some protection provided for the early-summer DUs (i.e. DU2 Bowron-ES, DU22 Taseko-ES), yet this does not occur on an annual basis. On dominant years for some of the more productive and abundant DUs (i.e. DU3 Chilko-ES, DU19 Shuswap-ES; not covered in RPA) there is considerable pressure to harvest, and these co-migrating weaker DUs are at threat of fisheries capture. This is also true for the other Summer and Late DUs covered in this RPA (e.g. DU17 Seton-L, DU21 Takla-Trembleur-S) which are at risk of co-harvest with stronger populations (e.g. DU4 Chilko-S, DU18 Shuswap-L Complex; not covered in RPA).

Fishery impacts can occur both in directed and non-directed fisheries. In addition to mortalities associated with retention of caught fish, there are also mortalities associated with fish that are released after capture and with fish that encounter but then escape the fishing gear. The impacts of fishing-related incidental mortality are well documented (Patterson et al. 2017a), yet the estimates of mortality are not well quantified. A process for quantifying fishing-related incidental mortality has been proposed and recommended (DFO 2016; Patterson et al. 2017b), yet has not been implemented into FRS stock-assessment modelling. Impacts from fisheries can be reduced by implementing different gear, time, and location measures. For example, stipulating shorter opening durations during FRS migration, shorter net set times, shorter nets, larger net mesh size, tangle tooth gear, and active fishing of set nets as opposed to passive fishing methods. The use of gill-nets has been identified as a major source of stress and injury to fish that become entangled and escape (see section 4.1.5.2), resulting in higher levels of pre-spawn mortality in FRS. Transitioning away from using gill-nets to alternative fishing gear is a potential option to reduce fisheries-related incidental mortality. Making use of brailing methods on seine boats facilitates recovery of released fish, as do recovery tanks when they are properly used (Cook et al. 2020). Recreational fisheries mitigation may include but is not limited to: use of gear which decreases impacts to released fish such as barbless hooks, mandatory fish handling and fish identification courses/exams (similar to a Conservation and Outdoor Recreation Education exam for hunting). Incorporating gear-specific temperature thresholds when opening fisheries that require the release of Sockeye in the Fraser River mainstem could assist with decreasing release mortalities. It is noted that while many of these protocols are already in place to mitigate fishing impacts, there is an unknown but potentially significant level of effect from non-compliance with these protocols. Increased monitoring and enforcement is needed to better understand and reduce the impacts of illegal fishing activity, both in the marine and freshwater environments.

Harvest activities and the recovery goals for these imperilled stocks needs to be in alignment in order to rebuild and given current low levels of escapement and productivity for some of the DUs covered in this RPA, any harvest may have significant negative impacts. Further to this, reduced harvest represents one of the few immediate mitigation actions we can control. DFO attempts to employ a precautionary framework to managing fisheries, which promotes caution when scientific knowledge is uncertain, and not using the absence of adequate scientific information as a reason to postpone action or failure to take action to avoid serious harm to fish stocks or their ecosystem[28]. Given the lack of information and uncertainty surrounding the impacts of mixed-stock fishing on severely depressed FRS DUs, particularly for DUs that must navigate the recent Big Bar slide in the mainstem Fraser River, all fishing pressure should be minimized to the greatest extend possible to prevent irreversible impacts. It is noted, however, that even in the absence of fishing these DUs are not expected to recover in the short term.

6.1.4. Forestry and wildlife management

Historical clear-cut logging and riparian vegetation removal have had significant negative impacts on stream channel stability, stream temperatures, runoff dynamics, seasonal hydrographs, and overall forest health throughout areas of the Fraser River basin. Current forestry practices aim to reduce these impacts by employing more sustainable and selective cutting rates, requiring buffer zones in riparian habitat, and considering information such as forest health/diversity, wildfire and fuel management, fish and wildlife status, climate change, and cumulative effects into timber management goals (BC Ministry of Forests, Lands & Natural Resources Operations [BCFLNRO] 2017). However, as discussed in section 4.1.7 the increasing frequency of wildfires, infestations and disease increase the threat of aggressive salvage logging operations as was seen following the outbreak of Mountain Pine Beetle in BC. These salvage operations typically cover larger areas than conventional cutblocks and can occur within riparian habitat due to exemptions for salvaging timber damaged by fire, insects, or disease suggesting that unless forest regulations and practices change, impacts from future salvage logging is probable. Future timber harvesting and salvage logging goals therefore need to align with the recovery goals of FRS, including both the physical impacts from these activities and more importantly, the larger implications on hydrological function through modified catchment surfaces. There are several pieces of provincial legislation in place to guide sustainable forestry practices both on public and private land, including the *Forest Act, Forest and Range Practices Act,* and *Private Managed Forest Land Act*, yet as with other sectors, these acts need to be updated regularly and require support for monitoring and enforcement. Changing legislation to eliminate or reduce aggressive salvage logging operations following forest disturbances, is also critical for the long-term recovery of FRS.

The lower Fraser River and estuary is a highly active area for log shipping and contains a high concentration of log booms and barges, which can lead to a variety of negative environmental effects in addition to salmon and salmon predators (see section 4.1.4.3 and 4.1.8.2). This area is known to support millions of outmigrating salmon which occupy marine foreshore areas after smoltification, and prior to migrating out to sea (Nelitz et al. 2012). Removals or reductions of current log storage areas in the lower Fraser River and estuary will likely improve the quantity and availability of nearshore habitat for FRS (and other Pacific salmon species) rearing in or travelling through the lower Fraser River and should be considered as a mitigation activity to improve habitat.

6.1.5. Invasive and problematic species

There are numerous invasive species present in the Fraser River basin, yet the majority of these species are not expected to pose a significant threat to FRS in the near future (see section Invasive Non-Native/Alien Species). Some of these species may, however, become a

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[28] DFO. 2009. A Fishery Decision-Making Framework Incorporating the Precautionary Approach.

more prevalent threat in the future if range expansion occurs, particularly in light of increasing average temperatures in southern BC (see section 4.1.11.1) which benefits more generalist species such as spiny-ray fishes (e.g. Bass spp., Yellow Perch). There has been a long history of failures to manage aquatic invasive species before irreversible damage has been done to ecosystems, both on the federal and provincial/state level in the Pacific Northwest (i.e. Columbia and tributaries), therefore early action is paramount in managing aquatic invasive species (AIS). Once AIS become established, they can be extremely difficult to manage without impacting native biological communities using conventional suppression techniques such as physical removal (netting, electrofishing) and chemical intervention (i.e. Rotenone). Where AIS are detected, all efforts to eradicate those species should be undertaken as quickly as possible and monitoring programs should be implemented and sustained to ensure eradication is complete. Detection of biological invasions in their early stages is, however, challenging when population densities are at a minimum, and conventional surveying techniques require considerable resources to conduct and have the potential to negatively impact non-target species, in addition to having questionable effectiveness when target species abundance is low (Olsen et al. 2015). The use of environmental DNA (eDNA) sampling has gained considerable interest since its inception (Ficetola et al. 2008) as a non-invasive technique to detect and monitor invasive or rare freshwater species, requiring minimal effort in the field and eliminating potential negative impacts on non-target species. The implementation of routine eDNA monitoring programs in likely areas of introduction may be an option to track the colonization and/or spread of AIS.

Pinniped predation, particularly by Harbour Seals, Stellar Seal Lions, and California Sea Lions, has been identified as a potentially significant source of FRS mortality, particularly for DUs with low abundances (see section 4.1.8.2). While there has been considerable work investigating the effects of predatory interactions between FRS and pinnipeds, there are a vast number of concurrent ecological processes that confound our understanding of these interactions and their impacts. There are few direct mitigation strategies available to reduce impacts of predation, with the exception of lethal removal (culling), non-lethal removal such as capture and relocation, or sterilization. A recent technical workshop hosted by the Institute for the Oceans and Fisheries (University of British Columbia), which included a broad group of scientists and managers from both Canada and the US with technical expertise on pinnipeds and salmonids, convened to evaluate the current state of knowledge and uncertainties surrounding the diets and population dynamics of pinnipeds, as well as the impacts that pinnipeds may be having on Pacific Salmon in the Salish Sea (Trites and Rosen 2019). The proceedings from this workshop go into considerable detail surrounding pinnipeds and their interactions with Pacific Salmon (see Trites and Rosen 2019); however, the general consensus from this workshop was that data are insufficient at this time to justify mitigation in the form of culling pinnipeds in the Salish Sea, due to high levels of uncertainty in the both our current state of information and the indirect effects of conducting a cull. Non-lethal alternatives such as capturing or harassing pinnipeds during critical times were also discussed, yet considerable thought would have to be given to implement such actions as to avoid habituation over time. As mentioned in section 4.1.5.1, log booms were identified to attract salmon seeking refuge, but also attract other predators and serve as haul-out sites for Harbour Seals. Removal of log booms in key areas, particularly in estuaries, may be beneficial in reducing the number of pinnipeds that predate on salmon seeking refuge. The use of contraceptives has also been put forth as an alternative non-lethal means of reducing pinniped abundance, yet there is currently limited information other than modelling studies estimating the potential effectiveness of sterilization under theoretical scenarios (Nelson 2020). There are a variety of ethical concerns and issues surrounding potential unintended biological effects, thus considerable research is needed to determine whether intervention through sterilization is warranted.

Further research is needed to better understand the indirect effects of culling predators and other factors that influence ecosystem function such as food web relationships, shifting prey/predator distributions, and hatchery practices. Further to this, with our limited understanding of both Pacific Salmon and pinniped population dynamics, we have little capability in determining whether removals are producing the intended effect. Further investigation of pinniped predation has been identified as a future research need for FRS mitigation planning and is noted in Appendix C.

6.1.6. Dams and water management

Threats identified in Element 8 include water extraction, hydroelectric development, and flood control structures (i.e. dikes, flood boxes, tide gates). In general, the current water extraction network in the Fraser River basin is difficult to govern, monitoring of surface extraction is inadequate, and monitoring of groundwater removal is almost non-existent. Though modern water licences are granted with metering requirements and within associated allocations, many water licences still exist that are unmetered. Water extraction in some river systems is now recognized to be over-allocated, but there are few options to retract licenses (Brown et al. 2019). Droughts are also becoming increasingly more frequent in the Fraser River basin (see section 4.1.11.2), and enforcement response in times of drought is frequently slow and until conditions are extreme. Re-evaluating levels of water extraction and licensing is going to be a critical component in maintaining appropriate water conditions for FRS and other salmonids, particularly in areas heavily prescribed for agriculture such as within DU16 (Quesnel-S). There is growing recognition in BC’s regulatory framework of the importance of aquifer sources to environmental needs. Section 55(4) of *The Water Sustainability Act* now clarifies that government has the discretion to consider environmental flow needs when adjudicating both new and pre-existing groundwater use. Though *The Water Sustainability Act*’s move to licence ground water is a step forward, there is still work required to incorporate current ground water wells into the regulatory framework, meter all extraction activities, and create water allocation regimes that include planning for fish-habitat requirements in order to sustain salmon habitat.

Seton Dam is the only facility with a fishway, and all Sockeye from DU17 (Seton-L) must pass through the fishway to reach spawning grounds in Portage Creek. There is evidence the Seton Dam fishway has negative impacts on migration of FRS from DU17, and poses confusing directional cues due to the presence of natal water in discharge from the generating station on the mainstem Fraser downstream from the confluence with Seton River (see section 4.1.7.2). In addition to maintaining and monitoring FRS passage success through the fishway at Seton Dam, mitigations in place to control the dilution of natal water at the Walden North facility will need to be continually monitored to ensure appropriate signalling cues are present to guide FRS into the Seton system. Temperature-related impacts in the lower Nechako River from Kenney Dam were also identified to threaten FRS returning the Stuart drainage (DU20 Takla-Trembleur-EStu, DU21 Takla-Trembleur-S). Current mitigations in place (i.e. Summer Temperature Management Program) generally prevent water temperatures from exceeding the threshold of 20 °C, yet with increasing average air temperatures in the Fraser River basin it will be important to actively monitor conditions and change protocols appropriately. In general, water release strategies at all impoundment structures must adhere to system-specific ecological flow requirements, which may be important for both adults and juveniles. Ecological flow requirements must include spring freshets to incorporate allochthonous material, clear sediments from spawning gravel, and introduce woody debris and inundate off channel habitat (Biggs et al. 2005). Water release must also be mindful of summer temperature and flow management requirements for FRS and other salmon species.

6.1.7. Pollution

A multitude of environmental contaminants and sources of pollution within the Fraser River basin were identified in section 4.1.9. Many of these contaminants are persistent in the environment, may travel long distances, and have a tendency to accumulate in sediments and food chains from multiple sources. Further to this, contaminants generated from multiple sources accumulate as mixtures in the environment therefore the effects from individual pollutants are extremely difficult to discern, and thus prioritize mitigation activities to reduce their harm.

The principal pieces of legislation in place for environmental pollution issues in British Columbia include the provincial *Environmental Management Act* and *Waste Discharge Regulation*, and the federal *Canadian Environmental Protection Act*, *Fisheries Act,* and *Canada Water Act*. Legislation and operational changes over the last several decades have been effective in reducing pollution from a variety of sectors, and while current legislation/regulation aims to reduce environmental contamination, the effects of historical activities still pose a noteworthy threat to FRS at all life stages. This is particularly true within the lower Fraser River and estuary, which has historically been the epicenter of anthropogenic activities within the province that generate pollution, in addition to serving as a bottleneck for pollutants accumulated throughout the Fraser River basin. All FRS must transit the lower Fraser and estuary during outmigration to the ocean and during their return spawning migration, and are thus exposed to environmental pollutants twice within these areas.

One of the few current options we have available for mitigating future pollution is the adoption and enforcement of more strict regulations on activities that generate and release contaminants into the environment. There are, however, inherent challenges in monitoring the release of pollution due to the vast number of sources within the Fraser River basin and surrounding coastal areas. This is particularly true when self-reliance of reporting and potential loss in revenue is involved. Monitoring programs like PollutionTracker[29] are currently working to document the levels and trends of a variety of contaminants within coastal BC. Public access to air quality on websites such as Purple Air[30] create transparency and encourage data sharing which may inspire individual responsibility to progress to improve air quality. Expansion of monitoring programs such as this would be beneficial for identifying and reducing the release of pollution that may impact FRS.

Remediation of polluted sites that are either within salmon habitat, or that influence salmon habitat through the release of contaminants (effluents, runoff, groundwater inputs, etc.), is another important component for mitigation planning. Remediation of contaminated sediments commonly employs activities such as dredging (mechanical or hydraulic removal of contaminated sediment), dry excavation (de-watering and physical removal of contaminated sediment), capping (covering contaminated sediments with clean material or geotextiles), the use of sorptive agents (mixing of sediments with reactive sorbants to isolate contaminants), and in-situ amendments (addition of chemicals/compounds to promote destruction or immobilization of contaminants) (Perelo 2010; Bullard et al. 2015). An alternative non-invasive mitigation strategy for contaminated sediments is monitored natural recovery (MNR), which relies on the metabolic potential of microorganisms, paired with naturally occurring physical and chemical processes to degrade contaminants over time (Perelo 2010; Bullard et al. 2015). Each of these mitigation strategies have a number of associated considerations in terms of their usefulness, feasibility, and sustainability, and should be thoroughly investigated on a project-specific basis.

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[29] Pollution Tracker 2021.

[30] Purple Air 2021.

Considerable work is needed in order to inventory and prioritize mitigation actions for pollution in the Fraser River basin and has been identified as a major knowledge gap that needs to be addressed for future recovery planning (Appendix C).

6.1.8. Climate change

Threats related to climate change encompass a large suite of complex and inter-related processes that both directly impact FRS through changes to environmental conditions beyond biological thresholds, in addition to exacerbating many of the threats discussed in section 4.1. These cumulative impacts may impede progress on many of the previously recommended mitigation measures. For example, more extreme precipitation events caused by climate change will compound with the increased run-off rates that result from logging and forest fires. Impediments to mitigation activities for those threats may occur through creation of new impoundment structures, increased failures of tailings ponds and water treatment facilities that introduced effluent, as well as higher rates of scouring and the increase in the likelihood of bank failure and of avulsion events. In addition, failures of infrastructure due to extreme events may lead to a greater number of in-stream work that may in turn contribute to threats as discussed under the Development threats section (4.1.1).

The current regulatory framework and best practices with regard to emergency works, water and tailings dam planning and management, forestry cut rates and block planning, bridge engineering, storm-water management and occupation of flood plains through urban encroachment may all need to be reconsidered to mitigate for the more regular arrival of higher flood flows, and altered snowpack melt regimes. The current practices of unregulated groundwater extraction, unmonitored surface water extraction activity, slow reaction times to drought conditions, and lack of planning around watershed-level hydrological function will all need to improve and be more responsive to climate change.

Combatting the effects of climate change is a global issue, and there are no simple measures available to mitigate the impacts in the short term. The changes in environmental conditions observed today have gradually shifted over many decades, and these effects are not anticipated to diminish or reverse in the foreseeable future. Considerable preparation and planning is needed to restore and conserve the remaining habitat available to FRS and other imperilled salmonids. The recent Paris Agreement[31] and the United Nations Intergovernmental Panel on Climate Change[32] provide guidelines to aid in the global effort of combatting and adapting to climate change, and FRS populations and their habitats should be managed according to these guidelines so that they are resilient and can adapt to future environmental changes.

6.1.9. Habitat enhancement and restoration

Habitat in the lower Fraser and estuary has been heavily degraded and fragmented since human settlement. While FRS are less reliant on rearing habitat in the lower Fraser River and estuary than other Pacific Salmon (e.g. Chinook, Pink, Chum), they migrate through this area twice in their life cycle and are threatened by a variety of unnatural conditions stemming from anthropogenic activity and flood control. Restoration of habitat within the lower Fraser River and estuary can increase valuable prey resources for juvenile salmon and other fishes, in addition to restoring more natural migratory corridors. However, significant modification or removal of existing development is required, potentially impacting human settlements. Removing engineered barriers to tidal exchange (i.e. tide gates, flood boxes), encouraging the formation of tidal channel networks, and increasing riparian vegetation in degraded habitats can improve

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[31] The Paris Agreement.

[32] Intergovernmental Panel on Climate Change.

invertebrate productivity and habitat complexity (Davis et al. 2019). The development of complex tidal channel networks with overhanging vegetation can lead to shaded waterways with more stable water temperatures (Beck et al. 2001; Bertness and Ewanchuk 2002; Whitcraft and Levin 2007), while also increasing predator avoidance and habitat structure for terrestrial prey (Kneib 1984; Allan et al. 2003; Woo et al. 2018). Recent habitat restoration efforts in the Nisqually River Delta, Washington, provide evidence that re-establishing tidal influences to a heavily modified estuarine ecosystem can increase prey resources and forage opportunities for juvenile salmon. Post-restoration monitoring data indicates substantial increases in invertebrate biomass following re-establishment of tidal inundation, greatly enhancing the foraging capacity for salmon (Woo et al. 2018). Habitat restoration in the lower Fraser would likely benefit DU24 (Widgeon-RT) the most due to their extended residence time in this area before outmigration to the Strait of Georgia, yet all FRS DUs would likely benefit from these efforts. There are currently efforts underway through a variety of organizations to restore marsh and tidal channel habitat in the lower Fraser River and to enhance connectivity within the Fraser River delta; i.e. the Fraser River Estuary Connectivity Project (Raincoast Conservation Foundation); Connected Waters (Watershed Watch Salmon Society); and Resilient Waters (MakeWay Foundation). Continued efforts such as these, in addition to more coordinated efforts to undertake meaningful restoration is needed.

There has been additional, and in some cases, significant degradation of FRS habitat within the interior Fraser River basin from historical resource extraction activities and development. Habitat restoration activities in the interior Fraser area that will have meaningful DU-level effects are challenging to employ due to the extensive geographic distribution of FRS, and in many cases, restoration would involve re-establishing natural catchment surfaces and flow regimes which is not possible in the short-term. Enhancement within some of these DUs may be a viable option to improve spawning and rearing conditions for FRS, and ultimately survival. Enhancement opportunities for FRS include lake fertilization, spawning channels, and hatcheries.

The majority of FRS nursery lakes in the Fraser River basin are considered to be oligotrophic and strongly nutrient deficient (Shortreed et al. 2001). Decomposing salmon carcasses have long been recognized as a source of marine-derived nutrients that play an important role in terrestrial ecosystem productivity (Stockner and Macisaac 1996; Gresh et al. 2000; Ebel et al. 2014). The annual influx of nutrients from returning salmon has been linked to increases in invertebrate biomass, juvenile fish production, and ecosystem carrying capacity (Cederholm et al. 1999; Naiman et al. 2002; Schindler et al. 2003; Kohler et al. 2013; Collins et al. 2016; Evans et al. 2019), and at historical abundances, nutrient inputs would typically exceed nutrient costs for growth of subsequent generations of juvenile salmon (Moore and Schindler 2004). In some ecosystems, however, reductions in salmon abundance has resulted in a major shift in their roles from net nutrient sources to nutrient sinks (Gende et al. 2002; Doughty et al. 2016; Evans et al. 2019), and this shift may have contributed to declines in salmonid abundance and diversity in general (Gresh et al. 2000). Lake fertilization is a potential mitigation strategy to compensate for reduced returns of adult salmon to natal ecosystems, and to improve the productive capacity of certain Sockeye-bearing systems. Lake fertilization theory is based on the assumptions that size advantages gained by Sockeye rearing in fertilized lakes will increase marine survival and adult returns, and juvenile biomass in the pelagic zones of lakes is primarily regulated by nutrient availability thus nutrient subsidies will benefit fish by increasing productivity on multiple trophic levels (Hyatt et al. 2004b; Collins et al. 2016). The efficacy of nutrient subsidy programs depends on a number of physical and biological factors such as food-web processes, plankton and fish community structure, environmental factors, and lake morphometry, and nursery lakes will, in general, respond differently to manipulations in nutrient availability (Stockner 1987; Kyle 1994). There is some debate as to the effectiveness of fertilization in most systems, and there are many complex and interrelated environmental factors that confound the true effects of nutrient additions into aquatic ecosystems. Further to this, concerns have been raised that fertilization of nursery lakes is interventionist and unnatural, yet some argue that most FRS DUs lie within unnatural habitat due to human activity (Hyatt et al. 2004b). Nonetheless, lake fertilization has been a widely practiced management tool in BC and the US for many decades, including within areas of the Fraser River basin.

Chilko Sockeye (DU3/4 Chilko-ES/S; not covered in RPA) have the longest and most consistently measured survival record for Pacific salmon in Canada, which has provided a unique opportunity to study the effects of lake fertilization on FRS (Akenhead et al. 2016). Chilko Lake was fertilized in 1988 and again in 1990–1993 following recommendations from (Shortreed and Stockner 1983), where inorganic fertilizer was applied throughout spring and summer to the central third of the Lake (Bradford et al. 2000). Primary and secondary production in the lake increased greatly each year that fertilizer was applied, and an increase in the average size of age-1 (34%) and age-2 smolts (58%) was reported by Bradford et al. (2000). Average recruits per spawner was 73% higher during fertilized versus unfertilized years yet there was considerable uncertainty in these estimates (confidence interval −2% to 174%; Hyatt et al. 2004). Bradford et al. (2000) reported a weak positive relationship between the size of age-1 smolts leaving Chilko Lake and their subsequent survival and concluded that fertilization may have increased adult production by improving the survival of smolts in the ocean. More recent work has indicated that additional factors may have confounded these results, such as the operation of a spawning channel that concurrently reduced the egg-to-smolt survival of broods 1988–2003, variable escapement and survival, and the effect of smolt abundance on the size of smolts (i.e. density-dependent growth; Akenhead et al. 2016). It has been suggested that fertilization of Chilko Lake had a negligible effect on productivity when considering these other factors, yet acknowledging that further examination of size, condition, parr and smolt density, smolt size and abundance, and returns at various ages is needed to clarify these effects (Akenhead et al. 2016). The outcomes of this fertilization program have been studied extensively since it occurred approximately 30 years ago, highlighting the difficulties and uncertainty in assessing the long term effects of such programs.

Nutrient subsidies in the Alouette Reservoir began in 1999 to improve the recreational fishery (Alouette Nutrient Restoration Program), and inorganic agricultural-grade fertilizer has been added weekly between May and September of each year and carefully monitored to increase plankton and nerkid (anadromous Sockeye Salmon and Kokanee) production (van Poorten et al. 2018). FRS from this DU (DU26 Alouette-ES) became extirpated following construction of the Alouette Dam in 1928, yet Kokanee have persisted in the lake and have retained the ability to become anadromous if smolts are allowed to migrate out from Alouette Reservoir (van Poorten et al. 2018). Plankton community structure and nutrient levels have been monitored continually in an attempt to maximize edible phytoplankton while minimizing the risk of plankton bloom. Increased nutrient load in the reservoir resulted in marked increases in mean annual zooplankton densities, and nerkid growth and size-at-age immediately increased as a result of increased zooplankton densities. The increase in body size led to higher fecundity in females, and increased abundance and survival of both age-0 nerkids and older age classes were observed. As zooplankton and nerkid abundance stabilized, nerkid body size also stabilized with slightly larger size-at-age than before nutrient additions. While the benefits on productivity for resident Kokanee in Alouette Lake has been apparent in the short-term, this is a relatively closed and unique system due to the presence of the dam. The authors highlight that it would take substantial anadromous Sockeye returns to re-establish pre-dam nutrient inputs into the system (Scott et al. 2017), and nutrient subsidies would have to be reduced with increases in salmon abundance leading to an overall increase in competitors to the system without improving growing conditions (Hebert et al. 2015; van Poorten et al. 2018). As such, they advise caution when considering the Alouette system as a case study for lake fertilization, and highlight future studies need to consider trophic interactions in long term recovery goals.

Adams Lake is a strongly oligotrophic lake that has received nutrient subsidies in the past (1997; Hume et al. 2003), and there are current plans to resume lake fertilization in the spring of 2021[33]. Following the initial fertilization event (Hume et al. 2003) an increase in all resident major zooplankton species (*Daphnia thorata, Eubosmina longispina, Diacyclops bicuspidatus thomasi,* and *Leptodiaptomus ashlandi*) was observed, and *Daphnia* in particular made up more than 80% of Sockeye diet during the fertilized year (Hyatt et al. 2004b). Comparisons of age-1 smolt weight from an unfertilized brood year (1992) with age-1 smolts from the fertilized year showed an increase in average weight 2.64 to 3.58 g (Hyatt et al. 2004b). This increase in smolt size would presumably increase marine survival, and Hume et al. (2003) indicate their restoration efforts appeared to have produced dramatic increases in returns relative to non-enhanced stocks. However, the authors highlight the need for more years of restoration data to determine whether the effects are statistically significant. The recent announcement of nutrient additions to Adams Lake indicates fertilization will begin in April 2021, in which liquid fertilizer will be added to the lake by boat on a weekly basis until late August. This work will continue through to 2024 and will potentially provide further insight into the effects of lake fertilization in oligotrophic lakes within the Fraser basin.

Additional examples of lake fertilization programs in BC, Alaska, and areas of the Pacific Northwest since the 1960s have been reviewed in detail by Hyatt et al. (2004). The authors of this review, and in general from the aforementioned studies, conclude that while almost all cases of lake fertilization are likely to yield positive gains in smolt biomass and may even contribute to increased marine survival, they also suggest that the potential for problems is significant. This includes, but is not limited to the high costs, algae blooms and increased production of competitor species (e.g. stickleback, mysids). Another consideration for nutrient additions to nursery lakes is light availability. The productivity of glacially turbid systems such as Taseko Lake (DU22) are strongly light-limited, therefore the likelihood of increasing lake productivity through nutrient subsidies is low (Shortreed et al. 2001). Given appropriate conditions, nursery lake fertilization may make significant contributions to the recovery of these and other depressed or threatened Sockeye Salmon populations (Hyatt et al. 2004), however, considerable caution must be taken to avoid unintended ecological consequences.

For systems with limited spawning habitat and underutilized nursery lake habitat, the creation of spawning channels may be beneficial for recovery. Spawning channels for Sockeye Salmon were developed in the 1960s as a means of increasing the production of fry to nursery lakes (Hilborn 1992). A spawning channel is an artificial stream with regulated flow and spawning gravel size designed to compensate for degraded habitat, provide protection from flooding and freezing, and in many cases make use of the underutilized rearing capacity of some lakes (Hilborn 1992; Shortreed et al. 2001). The basic assumption behind a spawning channel is that producing more fry will result in more returning adult fish (Hilborn 1992), which relies on several assumptions: (1) artificial channels can produce additional fry; (2) the viability of fry produced in the spawning channel would be comparable with that of naturally produced fry; (3) the attached nursery lake has the capacity to support higher abundances of fry; and (4) increasing juvenile production in the nursery lake will lead to a corresponding increase in the number of returning adults (McDonald and Hume 1984). There are also considerations of factors such as how many fish can a particular channel support, and how to clean spawning substrates to avoid accumulation of silt, debris, and disease outbreaks as channels age.

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[33] Adams Lake Indian Ban Press Release.

There have been several Sockeye spawning channels constructed within the Fraser River system, which serve three major purposes: (1) to mitigate for habitat losses as a direct result of development (e.g. Seton system); (2) to compensate for losses due to natural spawning ground deterioration or instability caused by watershed development and adjacent land use (e.g. Weaver, Gates); and (3) to enhance natural fry production in restricted spawning environments adjacent to a rearing habitat with large underutilized rearing potential (e.g. Nadina; Rosberg et al. 1986). There are several operational spawning channels for FRS (e.g. DU1 Anderson-Seton-ES (Gates), DU8 Nadina-Francois-ES (Nadina), DU10 Harrison (U/S)-L (Weaver), DU16 Quesnel-S (Horsefly).

The two spawning channels within DUs considered in this RPA, Weaver (DU10) and Horsefly (DU16), have been in operation since 1965 and 1989, respectively (Hilborn 1992), and Weaver Creek produces the majority (67%) of FRS via enhancement (Stephen et al. 2011). The Weaver spawning channel supports approximately 45,000 adults[34] and was the first of its kind for FRS under the International Pacific Salmon Fisheries Commission. The channel was specifically constructed to augment declining natural production attributed to the unstable nature of the watershed as a result of forestry practices (Rosberg et al. 1986). This instability was most apparent in 1952 when dewatering occurred and 15,000 adults (approximately 30% total spawners) died (Rosberg et al. 1986). Weaver Creek has insufficient flows to supply both the spawning channel and maintain downstream flows and uses two alternative water sources. There is a small intake dam located on Sakwi Creek which is used when necessary to divert flow into the Weaver intake (Rosberg et al. 1986). There is also a gravity fed pipe siphon from the outlet of Weaver Lake that transports water approximately 200 m downstream of the lake outlet. When low water conditions in Weaver Creek do not permit sufficient channel input, the Sakwi diversion is activated, and if these two sources do not maintain sufficient flows, the Weaver Lake siphon is activated. Numerous problems have been identified since Weaver channel became operational in 1965. Rosberg et al. (1986) discusses these issues in detail, but in summary, include: flooding, sedimentation issues, physical blockages (e.g. logs, woody debris), algae blooms, disease, frazil ice formation, poor water quality (dissolved oxygen), entrainment of air in water pipelines, poor migratory conditions, nutrient loading from organic material, and difficulties with Sockeye entering the channel. These series of events has, however, increased our knowledge of spawning channel engineering and operations, and continues to provide a wealth of knowledge for construction of future spawning channel projects.

The Horsefly spawning channel has been in operation since 1989 and was originally constructed to rebuild abundance in subdominant and off-cycle years for the Horsefly component of DU16. The channel is not in operation on an annual basis; it is generally considered that there is enough natural spawning habitat to produce fry abundances that meet or exceed the rearing capacity of Quesnel Lake, and in most cases does not operate on high-abundance years (Holmes 2009). In years when the channel is in operation it accommodates approximately 23,000 individuals (12,500 females) that are allowed to enter and spawn[35]. Operational issues have been identified with the channel, and its design (along with the design of the Chilko spawning channel) was criticized by Hilborn (1992). The Horsefly spawning channel was constructed downstream of the Moffat Creek confluence, which discharges high levels of sediment during freshet that accumulates within spawning gravels (Holmes 2009). The channel was also constructed on a low-grade which contributes to the accumulation of silt, and as a result, gravel cleaning is necessary on an annual basis in which the accumulated silt is mechanically and hydraulically removed (Holmes 2009). Despite these issues, the Horsefly

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[34] Weaver Creek Spawning Channel.

[35] Horsefly Spawning Channel.

channel provides spawning habitat that increases egg-fry survival for FRS and can provide a benefit for DU16.

In summary, spawning channels are a useful tool for Sockeye Salmon enhancement, yet the above examples highlight the need for careful preparation, planning, and monitoring when implementing and managing spawning channels as to avoid a variety of potential negative impacts.

Following the landslide at Big Bar there has been considerable effort to initiate emergency conservation enhancement for the most imperilled DUs (DU2 Bowron-ES, DU20 Takla-Trembleur-EStu, DU22 Taseko-ES), which has involved broodstock collection at a fish wheel downstream of the landslide, and artificially rearing eggs and fry for release into natal tributaries with the DUs (see section 6.1.9 for summary of enhancement work to date). Potential threats associated with hatchery enhancement were identified in Element 8 (sections 4.1.2.3 and 4.1.8.3), and are primarily associated with competition and loss of genetic diversity and fitness through unnatural selection pressures. Collection of broodstock from non-natal areas can create some uncertainty with respects to stock identification at the DU and deme level, and while these efforts are largely an attempt to prevent extirpation of these DUs, there is the potential for genetic impacts through these activities. An overall conservation enhancement plan is needed to assess all the risks and benefits associated with specific enhancement activities, as there is currently no science document that exists to aid in planning conservation enhancement in response to events such as the Big Bar landslide or emergency listings for salmon.

6.1.10. Conclusions

A major takeaway from this discussion is that a rapid change in human practices is needed to reduce further, and potentially irreversible impacts on FRS and the other imperilled Pacific Salmon species in the Fraser (Interior Fraser Coho, Interior Fraser Steelhead, Fraser Chinook). More recognition and emphasis of the cumulative effects many human activities have is needed within management from all sectors. Further to alleviating future threats, there is also a great need to restore historical damages from development and resource extraction activities that continue to impact hydrologic function within the Fraser River basin. Re-stabilization of more natural hydrological regimes and restoration of highly degraded habitat would facilitate work to address many of the aforementioned issues negatively impacting freshwater and estuarine productivity. These are, however, multi-generation endeavors, and effective mitigation is only possible if future management and planning from all sectors is in line with the recovery goals of FRS. It is also noted there are inherent challenges in mitigating many of the threats identified in section 4.1, as many are exacerbated by climate change.

A common theme within the mitigation categories discussed above is that a more coordinated and informed approach to managing anthropogenic activities is needed. Undertaking a more coordinated approach would promote more efficient use of limited human resources and facilitate access to the broad range of specialists required to develop such a strategy and manage its implementation over time. There is also a need to incorporate adaptive management strategies when planning mitigation activities, including current research on land use changes, intra- and interspecific competition, changing ocean and estuarine habitat conditions, and climate change, in addition to being regularly updated based on new information (Maas-Hebner et al. 2016).

Shortreed et al. (2001) conducted an extensive review of the limiting factors and enhancement potential for a number of Sockeye nursery lakes in BC and put forth recommendations to increase production and carrying capacity for these systems. They also highlight the information needed to determine the feasibility and success of restoration or enhancement projects within these systems, yet the data presented in their study is outdated and likely does not reflect current conditions. Despite this, the type of restoration and enhancement activities reported in Shortreed et al. (2001), and their rationale, are generally still relevant for the FRS DUs considered in this RPA. A notable exception is DU16 (Quesnel-S), which has seen considerable declines in abundance since Shortreed et al.'s (2001) publication, in addition to the occurrence of the Mount Polley tailings pond breach (discussed in section 4.1.3.1) which has had an unknown, but undoubtedly negative effect on the Quesnel Lake ecosystem. There has been considerable work conducted since the event to monitor changes in the ecosystem, and further additions of inorganic nutrients to the lake through fertilization will likely confound these monitoring efforts.

Table 39 provides a list of general mitigation activities that address the threats identified in Element 8 (section 4.1). Table 40 provides a DU-specific summary of anthropogenic threats, limiting habitat factors for productivity, and mitigation activities that would have potential positive benefits for FRS.

Table 39. Possible mitigation strategies to address threats to FRS identified in Element 8 (section 4.1).

COSEWIC Major Threat Category	Threat Category Description	Possible Pathway(s)	Possible Mitigation Options	Notes
Residential & commercial development	• Footprints of residential, commercial, and recreational development	• Loss or degradation of habitat	• Manage ongoing and future development in the context of salmon habitat requirements, mandate and monitor compensatory works for loss of habitat	-
Agriculture & aquaculture	• Footprints of agriculture, horticulture, and aquaculture • Competitive interactions with hatchery fish	• Loss or degradation of habitat • Competition	• Manage ongoing and future activities/development in the context of salmon habitat requirements, mandate and monitor compensatory works for loss of habitat • Transition to closed containment aquaculture	• Note that there is a large amount of surplus hatchery production outside of the Fraser River
Energy production & mining	• Footprints and extraction activities from mining (e.g. gravel extraction, placer mining, etc.).	• Loss or degradation of habitat	• Manage ongoing and future activities/development in the context of salmon habitat requirements, mandate and monitor compensatory works for loss of habitat	• Mount Polley tailings pond breach is a notable example; currently unknown extent of habitat degradation
Transportation & service corridors	• Footprints from roads, railroads, utility and service lines, and shipping lanes	• Loss or degradation of habitat	• Manage ongoing and future activities/development in the context of salmon habitat requirements, mandate and monitor compensatory works for loss of habitat • Use salmon friendly stream crossings (e.g. free span bridges, baffles, etc.), upgrade old passages (e.g. hanging culverts)	-
Biological resource use	• Logging and wood harvest in riparian areas, transport of logs via rivers • Fishing	• Loss or degradation of habitat • Direct and indirect mortality	• Update/improve forestry policy in the context of protecting and restoring salmon habitat and riparian areas, managing the time and abundance of log booms in river, monitor and enforce water quality requirements for salmon health • Manage the time and abundance of log booms in river, monitor and enforce water quality and effluent targets around booms • Adaptive fisheries management, increased monitoring and enforcement, minimize fisheries-related mortality (direct and incidental), education on identification of salmonids and conservation concerns	• Fishing effects are transboundary and are associated with mixed stocks and mixed species
Human intrusions & disturbance	• Recreational activities (e.g. ATVs in streams, jet boats, etc.)	• Loss or degradation of habitat • Direct and indirect mortality • Alteration of behaviour	• Manage access (e.g. infrastructure) to water and allowable activities (e.g. regulations) over time and space, increased monitoring and enforcement • Increased education on interacting with streams and salmon	-

COSEWIC Major Threat Category	Threat Category Description	Possible Pathway(s)	Possible Mitigation Options	Notes
Natural systems modifications	• Fire and fire suppression • Dams and water Management • Modifications to catchment surfaces, forestry	• Loss or degradation of habitat • Direct and indirect mortality • Alteration of behaviour	• Update/improve forestry policy in the context of conserving watershed functions that support salmon; mandate, monitor, and manage reforestation and restoration activities (including managing for mature forest characteristics) • Use strategic burning to prevent large fires • Manage ongoing and future development of water resources, increase monitoring and enforcement of surface and ground water, specifically with salmon biological requirements as targets • Decommission or remove dams, increase, monitor, and maintain fish passage infrastructure for adults and juveniles (fishways, fish ladders, etc.) • Adaptively manage water in the face of climate change and increased variability • Manage ongoing and future linear developments by imitating more natural waterways, reconnecting off-channel habitat, removing or restoring old developments, and set and monitor water quality and sediment targets • Consider the impacts of cumulative effects in decision making	-
Invasive & other problematic species & genes	• Aquatic invasive species (AIS), introduced pathogens and viruses, problematic native species (e.g. pinnipeds, parasites, and disease), interbreeding with hatchery-origin fish	• Loss or degradation of habitat • Alteration of behaviour • Predation and competition • Increased prevalence of infection • Reduced genetic diversity and natural selection forces	• Removals of AIS, prevention of introduction through increased monitoring for new and of existing AIS populations, increased enforcement and education surrounding introductions of AIS • Monitoring and treatment of pathogens in aquaculture, transition to land-based aquaculture and increased treatment of aquaculture effluent, implement and monitor predator control measures • Reductions in log booms in lower Fraser and estuary that serve as haul-out sites for pinnipeds • Monitor hatchery and wild genetics and implement adaptive production planning, mass mark hatchery fish to identify and remove from natural breeding population, minimize hatchery production	• Pinniped populations have increased due to protection of marine mammals; research is required on the efficacy and direct applicability of predator controls

COSEWIC Major Threat Category	Threat Category Description	Possible Pathway(s)	Possible Mitigation Options	Notes
Pollution	• Introduction of exotic and/or excess materials or energy from point and nonpoint sources, including nutrients, toxic chemicals, and/or sediments from urban, commercial, agricultural, and forestry activities	• Altered behaviour and physical condition due to hormone and developmental que mimics, gene regulation, and other toxicities, potentially reducing survival and resilience	• Manage ongoing and future activities/developments that contribute to pollution, improve waste water management and monitoring, increase enforcement of best practices for water quality • Removal or remediation of contaminated sediments	• Ongoing effects from Mount Polley tailings pond breach; continued monitoring an research needed to determine the magnitude of impacts
Geological events	• Avalanches and landslides	• Stop or reduce passage • Increased mortality associated with passage	• Increase, monitor, and maintain fish passage infrastructure for adults and juveniles (e.g. fishways, fish ladders, etc.) • Proactively identify areas that are at risk of landslides that could result in passage impediments, and implement regular monitoring to decrease mitigation response times to initiate mitigation activities	• Ongoing effects from Big Bar landslide
Climate change & severe weather	• Freshwater and marine habitats shifting, and increasing frequency of severe weather events (e.g. droughts, floods, temperature extremes, etc.)	• Loss or degradation of habitat • Direct and indirect mortality • Exacerbate impacts from other threats	• Follow guidelines from the recent Paris Accord and International Panel on Climate Change reports • Proactively manage habitats and populations so that they are resilient and may adapt to future changes	• Adaptive management is required for all mitigation activities in the context of climate change and the increased frequency of severe weather events

Table 40. Summary table listing threats and limiting factors for FRS DUs, and potential mitigation or enhancement activities that are feasible within three generations (2021-2032; time period for threats assessment). It is noted the mitigation and enhancement activities listed in the "Management Activities" column are not necessarily recommended activities, rather activities that have the potential to increase survival and/or production within the assessment time period.

DU	Threats & Limiting Factors	Management Activities (<3 Generations)	Comments
DU2 Bowron-ES High - Extreme	**Threats:** • Geological events (M-H) • Climate Change (M-H) • Ecosystem Modifications (M-H) • Fishing (M) • Aquaculture (L-M) • Problematic Native Species (L-M) • Pollution (L-M) **Limiting Factors:** • Low escapement and fry recruitment	**Mitigation:** • Reduced harvest • Ensure passage through fishways (i.e. Big Bar, Hells Gate) • Update/improve forestry practices[1] **Enhancement:** • Hatchery enhancement ○ Efforts underway[23]	• Limited spawning habitat in Bowron system, Bowron Lake could support higher abundances of rearing FRS • DU in remote area within a provincial park, construction of spawning channels or lake fertilization in conflict with maintaining pristine habitats • [1]Appropriate planning for future salvage logging operations needed (diseased and/or fire-damaged timber) • [2]Brood collection conducted in 2020 following Big Bar landslide, fry artificially reared and will be released into Bowron system in 2021 • [3]Potential to improve enhancement efforts through collection and implantation of eggs in natural habitat
DU10 Harrison (U/S)-L High	**Threats:** • Climate Change (M-H), • Fishing (M-H), • Ecosystem Modifications (L-M), • Aquaculture (L-M), • Problematic Native Species (L-M), • Pollution (L-M) **Limiting Factors:** • Low escapement and fry recruitment • Advance in migration timing	**Mitigation:** • Reduced harvest • Ensure appropriate habitat conditions between Harrison River and Weaver channel (flow, temperature, oxygen levels)[1] **Enhancement:** • Spawning channel ○ Weaver spawning channel in operation ○ Ensure maintenance (flows, gravel cleaning, removal of fine sediments) • Hatchery enhancement ○ Efforts underway[2] • Lake fertilization	• Harrison Lake could support higher numbers of FRS • [1]High levels of pre-spawn mortality from fish exposed to high temperatures, low flows, insufficient water supply to accommodate advance in migration timing, low dissolved oxygen in Morris Lake • At higher fry abundance fertilization in Harrison Lake could be a potential benefit, and may benefit multiple species that utilize habitat within the Harrison (e.g. Chinook) • [2]Hatchery program paired with spawning channel may significantly increase production

DU	Threats & Limiting Factors	Management Activities (<3 Generations)	Comments
DU14 North Barriere-ES High	**Threats:** • Climate Change (M-H), • Ecosystem Modifications (M), • Fishing (M), • Aquaculture (L-M), • Problematic Native Species (L-M) • Pollution (L-M) **Limiting Factors:** • Low in-lake growth or survival • Nutrient limitation • Rearing capacity reached or exceeded in some years	**Mitigation:** • Reduced harvest • Update/improve forestry practices[1] **Enhancement:** • Lake fertilization[2]	• [1]Appropriate planning for future salvage logging operations needed (diseased and/or fire-damaged timber) • [2]On high escapement years fry recruitment likely exceeds productive capacity of nursery lake, fertilization of North Barriere Lake could be a potential benefit
DU16 Quesnel-S High	**Threats:** • Climate Change (M-H), • Fishing (M-H), • Geological events (landslides) (M), • Ecosystem Modifications (M), • Aquaculture (L-M), • Problematic Native Species (L-M), • Pollution (L-M) **Limiting Factors:** • Low escapements and fry recruitment • Low in-lake growth or survival • Nutrient limitation • Rearing capacity reached or exceeded in some years	**Mitigation:** • Reduced harvest • Ensure passage at Big Bar and other fishways (e.g. Hells Gate) • Ensure cattle do not have access to critical Sockeye habitat • Continued monitoring and remediation following Mount Polly event[1] **Enhancement:** • Spawning channel ○ Horsefly channel in operation[2]	• [1]Mounty Polley tailings bond breach has affected Quesnel Lake ecosystem, the impacts of which are currently unknown • [2]Issues identified with spawning channel design/location, low-grade area, accumulates sediment from Moffat Creek; adequate maintenance/management required

DU	Threats & Limiting Factors	Management Activities (<3 Generations)	Comments
DU17 Seton-L High - Extreme	**Threats:** • Geological events (landslides) (H), • Climate Change (M-H), • Fishing (M-H), • Ecosystem Modifications (M), • Aquaculture (L-M), • Problematic Native Species (L-M), • Pollution (L-M) **Limiting Factors:** • Low escapements and fry recruitment • Low spawning ground capacity • Low in-lake growth or survival • Nutrient limitation	**Mitigation:** • Reduced harvest • Ensure passage at Seton Fishway (i.e. adequate monitoring and operational management, maintenance) • Maintain appropriate levels of natal water discharge from the Seton River to minimize confusing migration cues • Remedial habitat work in areas impacted by Whitecap Creek landslide[1] **Enhancement:** • Spawning channel[2] • Hatchery enhancement[3]	• [1]Ongoing issues from Whitecap Creek landslide, habitat remediation could include stabilization of the slide area, reduce likelihood of future landslide events • [2]Limited spawning habitat available for this DU relative to large nursery lake, spawning channel in Portage area may be beneficial • [3]Potential benefit from artificial fry rearing and release into lake
DU20 Takla-Trembleur-EStu Extreme	**Threats:** • Geological events (landslides) (E), • Climate Change (H), • Fishing (L-M), • Ecosystem Modifications (M-H), • Aquaculture (L-M), • Problematic Native Species (L-M), • Pollution (L-M) **Limiting Factors:** • Low escapements and fry recruitment • Nutrient limitations in nursery lake(s)	**Mitigation:** • Reduced harvest[1] • Ensure passage at Big Bar and other fishways (e.g. Hells Gate • Maintain appropriate water release levels at Kenney Dam to mitigate high water temperatures in lower Nechako River **Enhancement:** • Hatchery enhancement ○ Efforts underway[2] • Lake Fertilization	• [1]No directed fishery on Early Stuart Sockeye yet harvest still occurs • [2]Brood collection for hatchery enhancement conducted in 2019 and 2020 following Big Bar landslide, Fry artificially reared, released into Takla/Trembleur systems 2020/2021 • [3]At higher fry abundance lake fertilization in Takla and Trembleur lakes could have potential benefits; however, at current abundances, effects likely negligible
DU21 Takla-Trembleur-S High	**Threats:** • Climate change (H) • Fishing (M-H) • Geological events (M) • Ecosystem Modifications (M) • Aquaculture (L-M), • Problematic Native Species (L-M), • Pollution (L-M) **Limiting Factors:** • Low escapements and fry recruitment • Nutrient limitations in nursery lake(s)	**Mitigation:** • Reduced harvest • Ensure passage at Big Bar and other fishways (e.g. Hells Gate) • Maintain appropriate water release levels at Kenney Dam to mitigate high water temperatures in lower Nechako River **Enhancement:** • Lake fertilization[1]	• [1]At higher fry abundance lake fertilization could be a potential benefit (i.e. Takla and Trembleur lakes only; Stuart Lake is more productive than most Sockeye nursery lakes in BC, fertilization not recommended

DU	Threats & Limiting Factors	Management Activities (<3 Generations)	Comments
DU22 Taseko-ES High – Extreme	**Threats:** • Climate change (M-H) • Geological events (M-H) • Ecosystem Modifications (M-H) • Fishing (M-H) • Aquaculture (L-M), • Problematic Native Species (L-M), • Pollution (L-M) **Limiting Factors:** • Low escapements and fry recruitment • Nutrient limitations in nursery lake	**Mitigation:** • Reduced harvest • Ensure passage at Big Bar and other fishways (e.g. Hells Gate) **Enhancement:** • Hatchery enhancement ○ Efforts underway[1]	• Nursery lake light-limited due to glacial sediment inputs, lake fertilization unlikely to be effective at increasing nursery lake productivity • [1]Unsuccessful attempts have been made to collect brood stock following Big Bar landslide, future efforts likely • No stock-recruit time series for this DU
DU24 Widgeon-RT High	**Threats:** • Climate change (M-H) • Fishing (M-H) • Aquaculture (L-M) • Ecosystem Modifications (L-M) • Problematic Native Species (L-M) • Pollution (L-M) **Limiting Factors:** • Low spawning ground capacity • Rearing habitat in lower Fraser River highly degraded	**Mitigation:** • Reduced harvest • Habitat remediation in lower Fraser River[1] • Habitat protection and monitoring for area surrounding DU[23]	• [1]Limited quality rearing habitat in lower Fraser River, existing habitat highly degraded from historical status • [2]Recreational development (day-use area) planned within area surrounding this DU, appropriate protections and monitoring must be in place • [3]This is a low abundance DU with naturally limited spawning habitat, and mitigations are not anticipated to increase the supply of suitable habitat and thus abundance. Habitat protection is key for this DU to persist at low abundance. • No stock-recruit time series for this DU

6.2. ELEMENT 17: INVENTORY OF ACTIVITIES THAT COULD INCREASE THE PRODUCTIVITY OR SURVIVAL PARAMETERS

The majority of activities and discussed in Element 16 would benefit productivity or survival parameters for FRS DUs considered in this RPA. Table 39 provides a summary of general activities that address some of the threats identified in Element 8, and Table 40 provides DU-specific activities.

As stated in the above sections, DU24 Widgeon-RT is a low abundance population (<1,000 individuals) with naturally limited spawning habitat, and it is unlikely any activities or mitigations will increase the productivity or survival parameters of this DU. However, habitat protection within DU24 is, and will be vital to allow the DU to persist at this low abundance, which makes it particularly vulnerable to threats.

6.3. ELEMENT 18: IF CURRENT HABITAT SUPPLY WAS INSUFFICIENT TO ACHIEVE RECOVERY TARGETS (SEE ELEMENT 14), ADVICE ON THE FEASIBILITY OF RESTORING THE HABITAT TO HIGHER VALUES

The current habitat supply (discussed in section 5) was not deemed to be limiting these DUs from achieving their recovery targets (section 7). Refer to section 6.1 for an inventory of activities that may restore or enhance FRS habitat to higher values.

7. ELEMENT 22: ALLOWABLE HARM ASSESSMENT

The first part of the RPA addressed Elements 12, 13, 15, 19-21 of the Terms of Reference (i.e. quantitative analysis of recovery targets, probability of achieving recovery targets), and summarizes how these elements would contribute to allowable harm (DFO 2020). At that time no definitive allowable harm statements could be made prior to completion of the habitat and threats assessment presented here. This section summarizes findings from both RPA documents for each FRS DU, and provides a final allowable harm statement based on the collective results.

Allowable harm is broadly defined as: “harm to the wildlife species that will not jeopardize its recovery or survival” (DFO 2014c). It is important to note that **survival** represents a stable or increasing state where a species is not facing imminent extirpation, and **recovery** is a return to a state in which the population and distribution are within the normal range of variability (DFO 2014c). Two recovery targets were presented for FRS in DFO (2020):

1. **Recovery Target #1:** DU no longer characterized as Endangered or Threatened by COSEWIC or in the Red biological status of the Wild Salmon Policy (WSP);
2. **Recovery Target #2:** DU characterized as Not At Risk by COSEWIC, or Green biological status under WSP.

Recovery Target #1 is more indicative of survival (DU is not facing further declines and/or imminent extirpation), while Recovery Target #2 is more indicative of recovery (increased abundance and distribution within normal range of variability); however the results presented in part 1 of the RPA suggest the probability of Threatened or Endangered FRS DUs (i.e. all DUs covered in RPA) reaching Recovery Target #2 is highly unlikely in the next three generations (or 10 years for Widgeon-RT), and in some cases, reaching Recovery Target #1 is unlikely given current conditions. Preliminary results from 2020 spawner return data continue to support these conclusions (Ann-Marie Huang, DFO pers. comm. 2021).

The risk tables generated in part 1 of the RPA are provided in this section and illustrate the probability of each DU reaching Recovery Target #1 and #2 under current, and a range of potential future productivities and exploitation rates (ERs). As stated in DFO (2020): 1) ER was modelled because it is the easiest management lever to change quickly, and 2) **the ERs modelled should not be explicitly interpreted as an allowable fisheries exploitation rate on adult salmon**. ER in the recovery plots presented below should be interpreted as a combination of direct mortalities from anthropogenic sources (e.g., fishing); increases in mortality from indirect anthropogenic sources (e.g. en-route mortality exacerbated by ecosystems modifications, pollution, disease, climate change); and increases in mortality from historical levels of natural mortality (e.g., predation). The plots presented in this section were generating using the methods described in Part 1 of the RPA (DFO 2020a), but were updated to include data from brood years 2014-2016. The entire lower range of future productivities (i.e., 10-50% below current productivity) is considered plausible given rates of decline over the assessment time period. The range of higher productivities (i.e. 10-30% above current productivity) is presented more as a way to gauge potential effects from mitigation measures as opposed to representing expected near-future productivity trends.

Each FRS DU experiences a unique combination of threats depending on their migration timing, location of spawning habitat and life history, and some DUs are considered to be at a much higher level of risk. The allowable harm statement presented for each DU reflects the threat risk identified in Element 8 and the likelihood of reaching the recovery targets identified in Part 1 of the RPA. The following rationale was used to apply one of three allowable harm statements to each DU:

1. If a DU was estimated to have a “Very Unlikely” probability (0-10%) of reaching recovery target 1 at an exploitation rate great than or equal to 10%, and estimated to be at a High-Extreme (31-100% decline) or Extreme (71-100% decline) level of threat risk, the following recommendation is made:

   > it is our recommendation that the only activities allowed that cause mortality are those that are in support of the **survival** of the DU, and all sources of anthropogenic harm should be reduced to the maximum extent possible.

2. If a DU was estimated to have an “Unlikely” probability (0-33%), or As Likely As Not” probability (33-66%) of reaching recovery target 1 at an exploitation rate great than or equal to 10%, and estimated to be at a High (31-70% decline) or High-Extreme (31-100% decline) level of threat risk, the following recommendation is made:

   > it is our recommendation that the only activities allowed that cause mortality are those that are in support of the **survival or recovery** of the DU, and all sources of anthropogenic harm should be reduced to the maximum extent possible.

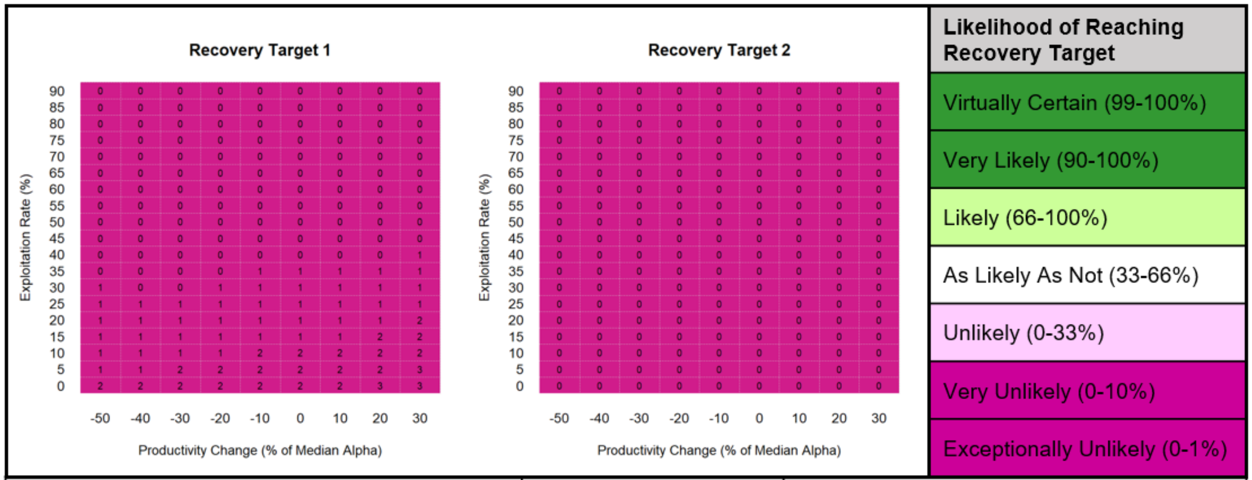
3. If a DU is naturally at low levels of abundance and is limited by habitat capacity (i.e. DU24 Widgeon-RT), it is susceptible to harm even if steps are taken to minimize mortality. As such:

   > it is our recommendation that the only activities allowed that cause mortality are those that are in support of the **persistence** of the DU, and all sources of anthropogenic harm should be reduced to the maximum extent possible.

The following sections are the summarized results of both parts of this RPA process with our final allowable harm recommendations:

7.1. DU2 BOWRON-ES

The threats assessment highlighted many significant threats to this DU that are unlikely to diminish in the near future, and these threats will likely continue to contribute to high levels of mortality (ranked High-Extreme; Table 36). The information presented in DFO (2020) and subsequent modelling work using 2020 return data has shown it is unlikely this DU will reach Recovery Target #1 in the next three generations (2021-2032) even in the most optimistic scenario of a 30% increase in productivity, zero exploitation rate, and cessation of impacts at Big Bar in future return years (Figure 29). Given that these scenarios are highly unlikely in the near future, **it is our recommendation that the only activities allowed that cause mortality are those that are in support of the *survival* of the DU, and all sources of anthropogenic harm should be reduced to the maximum extent possible.**



Recovery Target 1

Exploitation Rate (%)	-50	-40	-30	-20	-10	0	10	20	30
90	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	1
35	0	0	0	0	1	1	1	1	1
30	1	0	0	1	1	1	1	1	1
25	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	2
15	1	1	1	1	1	1	1	2	2
10	1	1	1	1	2	2	2	2	2
5	1	1	2	2	2	2	2	2	3
0	2	2	2	2	2	2	2	3	3

Productivity Change (% of Median Alpha)

Recovery Target 2

Exploitation Rate (%)	-50	-40	-30	-20	-10	0	10	20	30
90	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Productivity Change (% of Median Alpha)

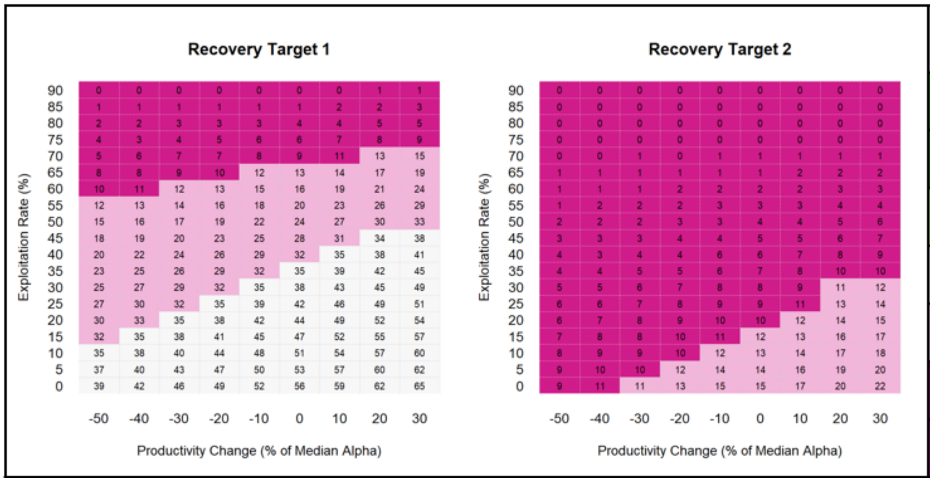
Likelihood of Reaching Recovery Target
Virtually Certain (99-100%)
Very Likely (90-100%)
Likely (66-100%)
As Likely As Not (33-66%)
Unlikely (0-33%)
Very Unlikely (0-10%)
Exceptionally Unlikely (0-1%)

COSEWIC Threat Category (Level 1)	Threat Ranking	Population-Level Impact (3 Generations)
1) Residential & Commercial Development	Negligible	N/A
2) Agriculture & Aquaculture	Low-Medium	1 – 30%
3) Energy Production & Mining	N/A	N/A
4) Transportation & Service Corridors	Negligible	N/A
5) Biological Resource Use	Medium	11 – 30%
6) Human Intrusions & Disturbance	Low	1 – 10%
7) Natural Systems Modifications	Medium-High	11 – 70%
8) Invasive & Other Problematic Species & Genes	Low-Medium	1 – 30%
9) Pollution	Low-Medium	1 – 30%
10) Geological Events	Medium-High	11 – 70%
11) Climate Change & Severe Weather	Medium-High	11 – 70%
OVERALL THREAT RANKING	High-Extreme	31 – 100%

Figure 29. Summary of the likelihood of reaching recovery targets (Part 1 of RPA) and threats assessment (Part 2 of RPA) for DU2 Bowron-ES.

7.2. DU10 HARRISON (U/S)-L

The threats assessment highlighted many significant threats to this DU that are unlikely to diminish in the near future (ranked High; Table 36). The threat ranking was decreased from High-Extreme to High, as while there are substantial threats facing this DU, observed trends in abundance do not suggest this DU is facing imminent extirpation. The modelling presented in DFO (2020) indicates that at ERs of 10% or less, this DU is As Likely As Not to reach Recovery Target #1 across most of the range of productivities modelled. It is either Unlikely or Very Unlikely for this DU to reach Recovery Target #2 within three generations (2021-2032) in all modelled scenarios. In order to provide the best opportunity for DU10 to meet Recovery Target #1, **it is our recommendation that the only activities allowed that cause mortality are those that are in support of the recovery of the species, and all sources of anthropogenic harm should be reduced to the maximum extent possible.**



Recovery Target 1

Exploitation Rate (%)	-50	-40	-30	-20	-10	0	10	20	30
90	0	0	0	0	0	0	0	1	1
85	1	1	1	1	1	1	2	2	3
80	2	2	3	3	3	4	4	5	5
75	4	3	4	5	6	6	7	8	9
70	5	6	7	7	8	9	11	13	15
65	8	8	9	10	12	13	14	17	19
60	10	11	12	13	15	16	19	21	24
55	12	13	14	16	18	20	23	26	29
50	15	16	17	19	22	24	27	30	33
45	18	19	20	23	25	28	31	34	38
40	20	22	24	26	29	32	35	38	41
35	23	25	26	29	32	35	39	42	45
30	25	27	29	32	35	38	43	45	49
25	27	30	32	35	39	42	46	49	51
20	30	33	35	38	42	44	49	52	54
15	32	35	38	41	45	47	52	55	57
10	35	38	40	44	48	51	54	57	60
5	37	40	43	47	50	53	57	60	62
0	39	42	46	49	52	56	59	62	65

Productivity Change (% of Median Alpha)

Recovery Target 2

Exploitation Rate (%)	-50	-40	-30	-20	-10	0	10	20	30
90	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0
70	0	0	1	0	1	1	1	1	1
65	1	1	1	1	1	1	2	2	2
60	1	1	1	2	2	2	2	3	3
55	1	2	2	2	3	3	3	4	4
50	2	2	2	3	3	4	4	5	6
45	3	3	3	4	4	5	5	6	7
40	4	3	4	4	6	6	7	8	9
35	4	4	5	5	6	7	8	10	10
30	5	5	6	7	8	8	9	11	12
25	6	6	7	8	9	9	11	13	14
20	6	7	8	9	10	10	12	14	15
15	7	8	8	10	11	12	13	16	17
10	8	9	9	10	12	13	14	17	18
5	9	10	10	12	14	14	16	19	20
0	9	11	11	13	15	15	17	20	22

Productivity Change (% of Median Alpha)

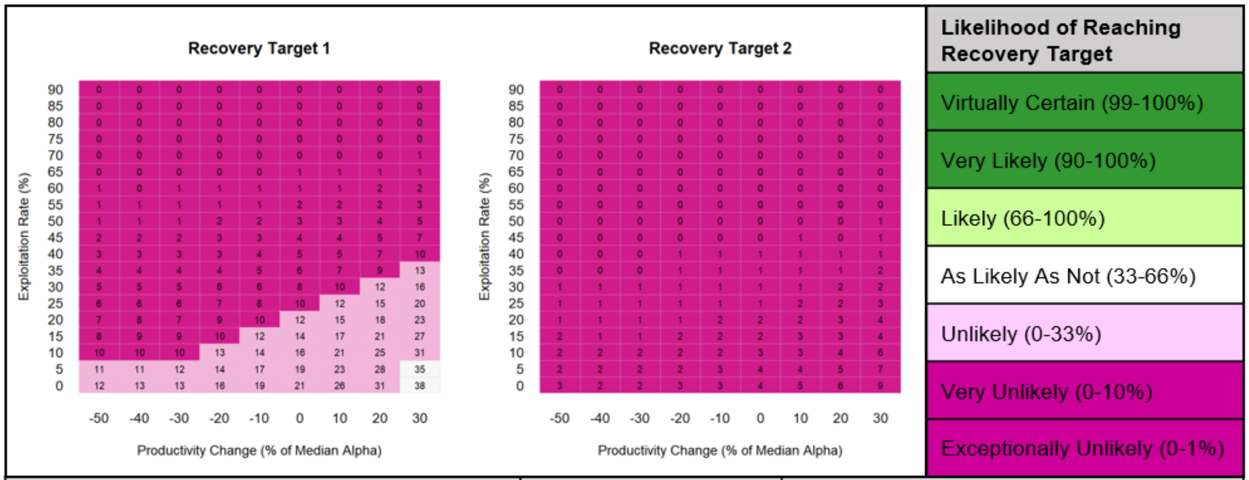
Likelihood of Reaching Recovery Target
Virtually Certain (99-100%)
Very Likely (90-100%)
Likely (66-100%)
As Likely As Not (33-66%)
Unlikely (0-33%)
Very Unlikely (0-10%)
Exceptionally Unlikely (0-1%)

COSEWIC Threat Category (Level 1)	Threat Ranking	Population-Level Impact (3 Generations)
1) Residential & Commercial Development	Negligible	N/A
2) Agriculture & Aquaculture	Low-Medium	1 – 30%
3) Energy Production & Mining	N/A	N/A
4) Transportation & Service Corridors	Unknown	N/A
5) Biological Resource Use	Medium-High	11 – 70%
6) Human Intrusions & Disturbance	Negligible	N/A
7) Natural Systems Modifications	Low-Medium	1 – 30%
8) Invasive & Other Problematic Species & Genes	Low-Medium	1 – 30%
9) Pollution	Low-Medium	1 – 30%
10) Geological Events	Negligible	N/A
11) Climate Change & Severe Weather	Medium-High	11 – 70%
OVERALL THREAT RANKING	High	31 – 70%

Figure 30. Summary of the likelihood of reaching recovery targets (Part 1 of RPA) and threats assessment (Part 2 of RPA) for DU10 Harrison (U/S)-L.

7.3. DU14 NORTH BARRIERE-ES

The threats assessment indicated this population is at a High-Extreme level of risk, and due to the low population size there is a possibility of this population being extirpated in the next three generations (2021-2032). This is a de novo population that was initially extirpated and rebuilt from hatchery stock, and is currently at very low abundance. The modelling presented in DFO (2020) shows that DU14 is As Likely As Not to reach Recovery Target #1 across a wide range of modelled future productivities at low to zero exploitation rates. Therefore, to provide the best opportunity for DU14 to meet Recovery Target #1, i**t is our recommendation that the only activities allowed that cause mortality are those that are in support of the survival and recovery of the species, and all sources of anthropogenic harm should be reduced to the maximum extent possible.**



Recovery Target 1

Exploitation Rate (%)	-50	-40	-30	-20	-10	0	10	20	30
90	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	1
65	0	0	0	0	0	1	1	1	1
60	1	0	1	1	1	1	1	2	2
55	1	1	1	1	1	2	2	2	3
50	1	1	1	2	2	3	3	4	5
45	2	2	2	3	3	4	4	5	7
40	3	3	3	3	4	5	5	7	10
35	4	4	4	4	5	6	7	9	13
30	5	5	5	6	6	8	10	12	16
25	6	6	6	7	8	10	12	15	20
20	7	8	7	9	10	12	15	18	23
15	8	9	9	10	12	14	17	21	27
10	10	10	10	13	14	16	21	25	31
5	11	11	12	14	17	19	23	28	35
0	12	13	13	16	19	21	26	31	38

Productivity Change (% of Median Alpha)

Recovery Target 2

Exploitation Rate (%)	-50	-40	-30	-20	-10	0	10	20	30
90	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	1
45	0	0	0	0	0	0	1	0	1
40	0	0	0	1	1	1	1	1	1
35	0	0	0	1	1	1	1	1	2
30	1	1	1	1	1	1	1	2	2
25	1	1	1	1	1	1	2	2	3
20	1	1	1	1	2	2	2	3	4
15	2	1	1	2	2	2	3	3	4
10	2	2	2	2	2	3	3	4	6
5	2	2	2	2	3	4	4	5	7
0	3	2	2	3	3	4	5	6	9

Productivity Change (% of Median Alpha)

Likelihood of Reaching Recovery Target

- Virtually Certain (99-100%)
- Very Likely (90-100%)
- Likely (66-100%)
- As Likely As Not (33-66%)
- Unlikely (0-33%)
- Very Unlikely (0-10%)
- Exceptionally Unlikely (0-1%)

COSEWIC Threat Category (Level 1)	Threat Ranking	Population-Level Impact (3 Generations)
1) Residential & Commercial Development	Negligible	N/A
2) Agriculture & Aquaculture	Low-Medium	1 – 30%
3) Energy Production & Mining	N/A	N/A
4) Transportation & Service Corridors	Negligible	N/A
5) Biological Resource Use	Medium-High	11 – 70%
6) Human Intrusions & Disturbance	Negligible	N/A
7) Natural Systems Modifications	Medium	11 – 30%
8) Invasive & Other Problematic Species & Genes	Low-Medium	1 – 30%
9) Pollution	Low-Medium	1 – 30%
10) Geological Events	N/A	N/A
11) Climate Change & Severe Weather	Medium-High	11 – 70%
OVERALL THREAT RANKING	High- Extreme	31 – 100%

Figure 31. Summary of the likelihood of reaching recovery targets (Part 1 of RPA) and threats assessment (Part 2 of RPA) for DU14 North Barriere-ES.

7.4. DU16 QUESNEL-S

The threats assessment highlighted many significant threats to this DU that are unlikely to diminish in the near future, and these threats will likely continue to contribute to high levels of mortality (ranked High; Table 36). It is noted that the overall ranking determined in the threats assessment was decreased from High-Extreme to High, as it is unlikely this stock will be extirpated within the next three generations (2021-2032) given high abundances compared to other populations considered in the RPA. There are, however, likely additional, albeit currently unknown impacts following the Mt. Polley disaster in 2014 that could lead to higher than anticipated declines. The information presented in DFO (2020) indicated DU16 is likely to reach Recovery Target #1 across most of the range of productivities modelled at modest ERs, yet it is highly unlikely that it will reach Recovery Target #2 in the next three generations given current estimated productivity and exploitation of summer-run FRS.

Recovery Target 1

Exploitation Rate (%)	-50	-40	-30	-20	-10	0	10	20	30
90	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	1	1	1	1
70	1	1	1	1	1	1	1	2	2
65	1	1	2	1	2	2	3	4	4
60	2	2	2	2	3	4	5	6	7
55	4	4	4	4	5	6	7	9	11
50	5	6	5	6	7	9	11	13	15
45	7	8	7	8	10	11	14	17	20
40	8	10	10	11	13	15	18	22	26
35	11	12	13	14	16	19	22	26	31
30	13	14	16	17	20	23	27	31	36
25	15	17	19	20	23	27	31	35	41
20	18	20	21	24	27	31	36	40	46
15	21	22	25	27	31	35	40	45	50
10	23	25	28	30	34	39	44	49	54
5	26	28	31	34	38	43	48	54	58
0	29	31	34	37	41	47	52	58	62

Recovery Target 2

Exploitation Rate (%)	-50	-40	-30	-20	-10	0	10	20	30
90	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	1
45	0	0	0	0	0	0	0	0	1
40	0	0	0	0	0	1	1	1	1
35	0	0	0	0	1	1	1	1	2
30	1	1	1	1	1	1	2	2	2
25	1	1	1	1	1	2	2	2	3
20	1	1	1	1	1	2	2	3	4
15	2	2	2	2	2	3	3	4	5
10	2	2	2	2	3	3	4	5	7
5	2	2	2	3	3	4	5	6	8
0	3	3	3	3	4	5	6	7	9

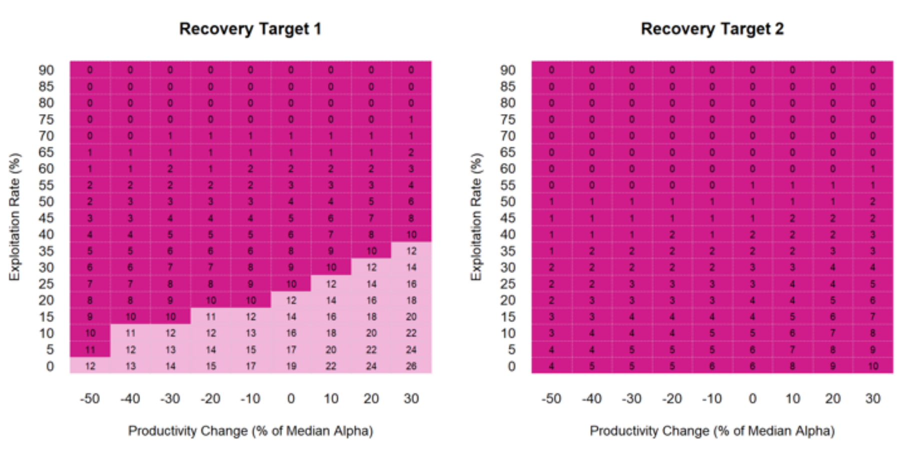
Likelihood of Reaching Recovery Target
Virtually Certain (99-100%)
Very Likely (90-100%)
Likely (66-100%)
As Likely As Not (33-66%)
Unlikely (0-33%)
Very Unlikely (0-10%)
Exceptionally Unlikely (0-1%)

COSEWIC Threat Category (Level 1)	**Threat Ranking**	**Population-Level Impact (3 Generations)**
1) Residential & Commercial Development	Negligible	N/A
2) Agriculture & Aquaculture	Low-Medium	1 – 30%
3) Energy Production & Mining	Unknown	N/A
4) Transportation & Service Corridors	Unknown	N/A
5) Biological Resource Use	Medium-High	11 – 70%
6) Human Intrusions & Disturbance	Low	1 – 10%
7) Natural Systems Modifications	Medium	11 – 30%
8) Invasive & Other Problematic Species & Genes	Low-Medium	1 – 30%
9) Pollution	Low-Medium	1 – 30%
10) Geological Events	Medium	11 – 30%
11) Climate Change & Severe Weather	High	30 – 70%
OVERALL THREAT RANKING	High	31 – 70%

Figure 32. Summary of the likelihood of reaching recovery targets (Part 1 of RPA) and threats assessment (Part 2 of RPA) for DU16 Quesnel-S

7.5. DU17 SETON-L

The threats assessment indicated this population is at a High-Extreme level of risk, and these threats are not anticipated to diminish in the near future. This is a single spawning site DU within a highly modified ecosystem, and due to the small population size there is a possibility of the DU being extirpated in the next three generations (2021-2032). The modelling presented in DFO (2020) shows that DU17 is As Likely As Not to reach Recovery Target #1 across a wide range of modelled future productivities at low to zero exploitation rates. Therefore, to provide the best opportunity for DU17 to meet Recovery Target #1, i**t is our recommendation that the only activities allowed that cause mortality are those that are in support of the survival and recovery of the species, and all sources of anthropogenic harm should be reduced to the maximum extent possible.**



Recovery Target 1

Exploitation Rate (%)	-50	-40	-30	-20	-10	0	10	20	30
90	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	1
70	0	0	1	1	1	1	1	1	1
65	1	1	1	1	1	1	1	1	2
60	1	1	2	1	2	2	2	2	3
55	2	2	2	2	2	3	3	3	4
50	2	3	3	3	3	4	4	5	6
45	3	3	4	4	4	5	6	7	8
40	4	4	5	5	5	6	7	8	10
35	5	5	6	6	6	8	9	10	12
30	6	6	7	7	8	9	10	12	14
25	7	7	8	8	9	10	12	14	16
20	8	8	9	10	10	12	14	16	18
15	9	10	10	11	12	14	16	18	20
10	10	11	12	12	13	16	18	20	22
5	11	12	13	14	15	17	20	22	24
0	12	13	14	15	17	19	22	24	26

Productivity Change (% of Median Alpha)

Recovery Target 2

Exploitation Rate (%)	-50	-40	-30	-20	-10	0	10	20	30
90	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	1
55	0	0	0	0	0	1	1	1	1
50	1	1	1	1	1	1	1	1	2
45	1	1	1	1	1	1	2	2	2
40	1	1	1	2	1	2	2	2	3
35	1	2	2	2	2	2	2	3	3
30	2	2	2	2	2	3	3	4	4
25	2	2	3	3	3	3	4	4	5
20	2	3	3	3	3	4	4	5	6
15	3	3	4	4	4	4	5	6	7
10	3	4	4	4	5	5	6	7	8
5	4	4	5	5	5	6	7	8	9
0	4	5	5	5	6	6	8	9	10

Productivity Change (% of Median Alpha)

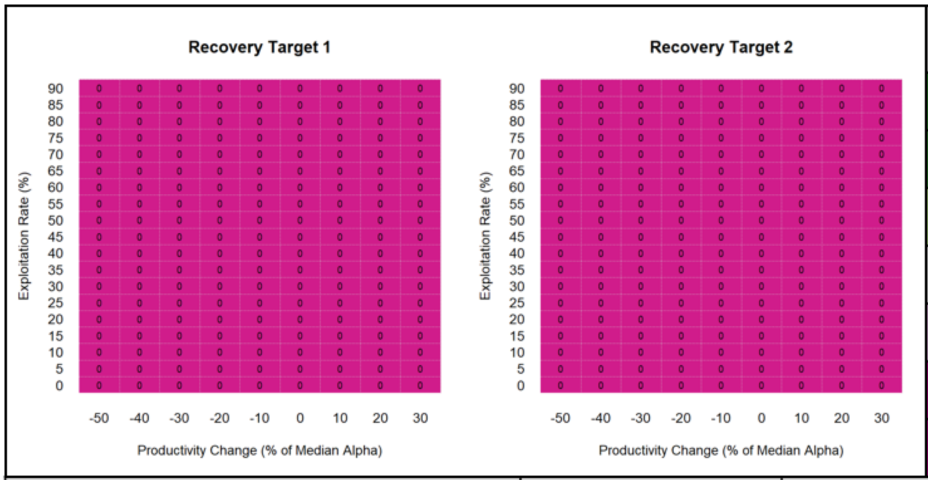
Likelihood of Reaching Recovery Target
Virtually Certain (99-100%)
Very Likely (90-100%)
Likely (66-100%)
As Likely As Not (33-66%)
Unlikely (0-33%)
Very Unlikely (0-10%)
Exceptionally Unlikely (0-1%)

COSEWIC Threat Category (Level 1)	Threat Ranking	Population-Level Impact (3 Generations)
1) Residential & Commercial Development	Negligible	N/A
2) Agriculture & Aquaculture	Low-Medium	1 – 30%
3) Energy Production & Mining	N/A	N/A
4) Transportation & Service Corridors	Unknown	N/A
5) Biological Resource Use	Medium-High	11 – 70%
6) Human Intrusions & Disturbance	Low	1 – 10%
7) Natural Systems Modifications	Medium	11 – 30%
8) Invasive & Other Problematic Species & Genes	Low-Medium	1 – 30%
9) Pollution	Low-Medium	1 – 30%
10) Geological Events	High	31 – 70%
11) Climate Change & Severe Weather	Medium-High	11 – 70%
OVERALL THREAT RANKING	High- Extreme	31 – 100%

Figure 33. Summary of the likelihood of reaching recovery targets (Part 1 of RPA) and threats assessment (Part 2 of RPA) for DU17 Seton-L.

7.6. DU20 TAKLA-TREMBLEUR-ESTU

The Early Stuart DU is the most threatened of all FRS; they have the longest migration distance (>1000 km); they have the earliest migration timing of all FRS and rely heavily on hydrologic conditions during migration; they spawn more unstable habitat that is more sensitive to temperature/flow impacts compared to other DUs. The threats assessment suggests this population is at an Extreme level of risk, and there is a real possibility of the DU being extirpated in the next three generations (2021-2032). The modelling work presented in DFO (2020) has indicated that it is highly unlikely for this DU to reach the lower Recovery Target #1 using all combinations of ER and productivity. As such, **it is our recommendation that the only activities allowed that cause mortality are those that are in support of the survival of the DU, and all sources of anthropogenic harm should be reduced to the maximum extent possible.**



Recovery Target 1

Exploitation Rate (%)	-50	-40	-30	-20	-10	0	10	20	30
90	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Productivity Change (% of Median Alpha)

Recovery Target 2

Exploitation Rate (%)	-50	-40	-30	-20	-10	0	10	20	30
90	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Productivity Change (% of Median Alpha)

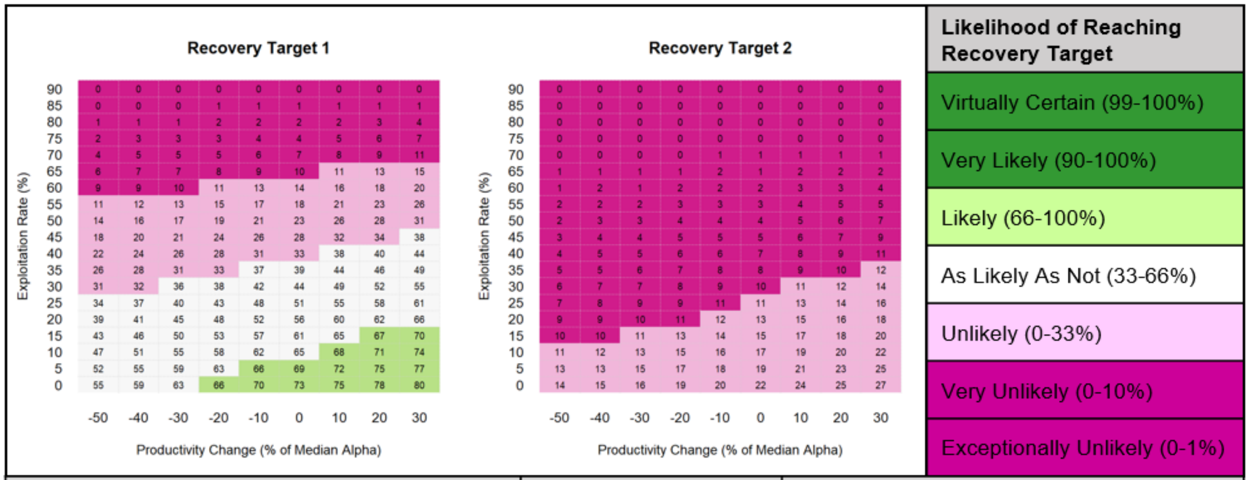
Likelihood of Reaching Recovery Target
Virtually Certain (99-100%)
Very Likely (90-100%)
Likely (66-100%)
As Likely As Not (33-66%)
Unlikely (0-33%)
Very Unlikely (0-10%)
Exceptionally Unlikely (0-1%)

COSEWIC Threat Category (Level 1)	Threat Ranking	Population-Level Impact (3 Generations)
1) Residential & Commercial Development	Negligible	N/A
2) Agriculture & Aquaculture	Low-Medium	1 – 30%
3) Energy Production & Mining	N/A	N/A
4) Transportation & Service Corridors	Negligible	N/A
5) Biological Resource Use	Low-Medium	1 – 30%
6) Human Intrusions & Disturbance	Low	1 – 10%
7) Natural Systems Modifications	Medium-High	11 – 70%
8) Invasive & Other Problematic Species & Genes	Low-Medium	1 – 30%
9) Pollution	Low-Medium	1 – 30%
10) Geological Events	Extreme	71 – 100%
11) Climate Change & Severe Weather	High	30 – 70%
OVERALL THREAT RANKING	Extreme	71 – 100%

Figure 34. Summary of the likelihood of reaching recovery targets (Part 1 of RPA) and threats assessment (Part 2 of RPA) for DU20 Takla-Trembleur-EStu.

7.7. DU21 TAKLA-TREMBLEUR-S

Summer-run Stuart Sockeye are less threatened than their earlier counterparts (DU20) due to their later return timing, yet this DU remains to be in serious peril. The threats assessment determined this population is at a High level of risk, which was decreased from High-Extreme as it is unlikely this stock will be extirpated within the next three generations (2021-2032) given current abundances. At ERs of 5% or less and with increasing productivities, DU21 is Likely to reach Recovery Target #1; however, as productivity decreases below current levels and at exploitation rates of 10% or less, this DU is As Likely As Not to reach Recovery Target #1. It is Unlikely – Very Unlikely this DU will reach Recovery Target #2 in the next three generations with all combinations of ER and productivity modelled. Given the collective results, **it is our recommendation that the only activities allowed that cause mortality are those that are in support of the survival and recovery of the species DU, and all sources of anthropogenic harm should be reduced to the maximum extent possible.**



Recovery Target 1

Exploitation Rate (%)	-50	-40	-30	-20	-10	0	10	20	30
90	0	0	0	0	0	0	0	0	0
85	0	0	0	1	1	1	1	1	1
80	1	1	1	2	2	2	2	3	4
75	2	3	3	3	4	4	5	6	7
70	4	5	5	5	6	7	8	9	11
65	6	7	7	8	9	10	11	13	15
60	9	9	10	11	13	14	16	18	20
55	11	12	13	15	17	18	21	23	26
50	14	16	17	19	21	23	26	28	31
45	18	20	21	24	26	28	32	34	38
40	22	24	26	28	31	33	38	40	44
35	26	28	31	33	37	39	44	46	49
30	31	32	36	38	42	44	49	52	55
25	34	37	40	43	48	51	55	58	61
20	39	41	45	48	52	56	60	62	66
15	43	46	50	53	57	61	65	67	70
10	47	51	55	58	62	65	68	71	74
5	52	55	59	63	66	69	72	75	77
0	55	59	63	66	70	73	75	78	80

Productivity Change (% of Median Alpha)

Recovery Target 2

Exploitation Rate (%)	-50	-40	-30	-20	-10	0	10	20	30
90	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0
70	0	0	0	0	1	1	1	1	1
65	1	1	1	1	2	1	2	2	2
60	1	2	1	2	2	2	3	3	4
55	2	2	2	3	3	3	4	5	5
50	2	3	3	4	4	4	5	6	7
45	3	4	4	5	5	5	6	7	9
40	4	5	5	6	6	7	8	9	11
35	5	5	6	7	8	8	9	10	12
30	6	7	7	8	9	10	11	12	14
25	7	8	9	9	11	11	13	14	16
20	9	9	10	11	12	13	15	16	18
15	10	10	11	13	14	15	17	18	20
10	11	12	13	15	16	17	19	20	22
5	13	13	15	17	18	19	21	23	25
0	14	15	16	19	20	22	24	25	27

Productivity Change (% of Median Alpha)

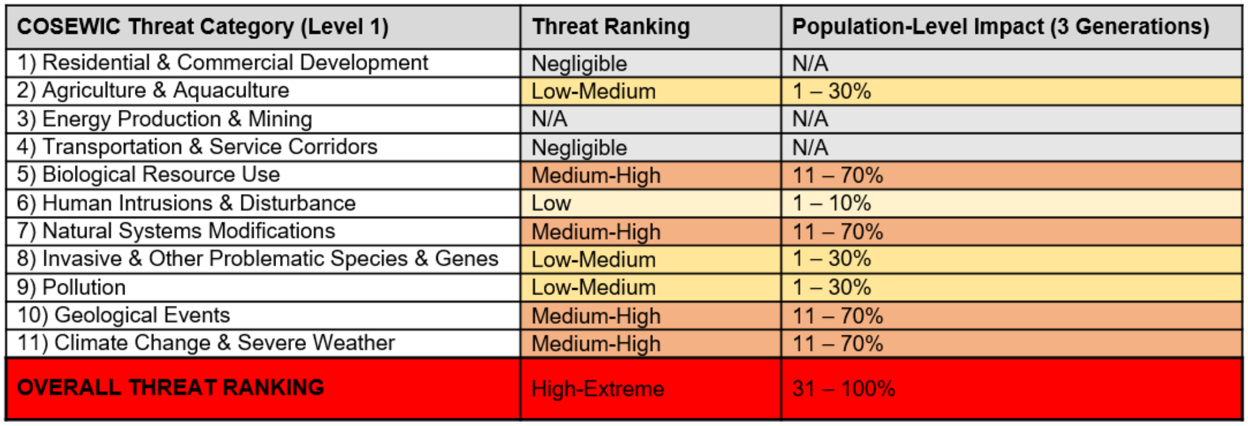
Likelihood of Reaching Recovery Target
Virtually Certain (99-100%)
Very Likely (90-100%)
Likely (66-100%)
As Likely As Not (33-66%)
Unlikely (0-33%)
Very Unlikely (0-10%)
Exceptionally Unlikely (0-1%)

COSEWIC Threat Category (Level 1)	**Threat Ranking**	**Population-Level Impact (3 Generations)**
1) Residential & Commercial Development	Negligible	N/A
2) Agriculture & Aquaculture	Low-Medium	1 – 30%
3) Energy Production & Mining	N/A	N/A
4) Transportation & Service Corridors	Negligible	N/A
5) Biological Resource Use	Medium-High	11 – 70%
6) Human Intrusions & Disturbance	Low	1 – 10%
7) Natural Systems Modifications	Medium	11 – 30%
8) Invasive & Other Problematic Species & Genes	Low-Medium	1 – 30%
9) Pollution	Low-Medium	1 – 30%
10) Geological Events	Medium	11 – 30%
11) Climate Change & Severe Weather	High	30 – 70%
OVERALL THREAT RANKING	High	31 – 70%

Figure 35. Summary of the likelihood of reaching recovery targets (Part 1 of RPA) and threats assessment (Part 2 of RPA) for DU21 Takla-Trembleur-S.

7.8. DU22 TASEKO-ES

The threats assessment indicates this DU is at a High-Extreme level of risk, as this is a small DU with very low abundance, and there is the potential for extirpation in the next three generations (2021-2032), particularly in light of the Big Bar landslide. Modelling was not conducted for this DU due to a lack of stock-recruit time series data, therefore no risk table is presented here; however, using the other small stocks assessed as proxies, and taking into account expected impacts from Big Bar, **it is our recommendation that the only activities allowed that cause mortality are those that are in support of the survival and recovery of the species, and all sources of anthropogenic harm should be reduced to the maximum extent possible.**



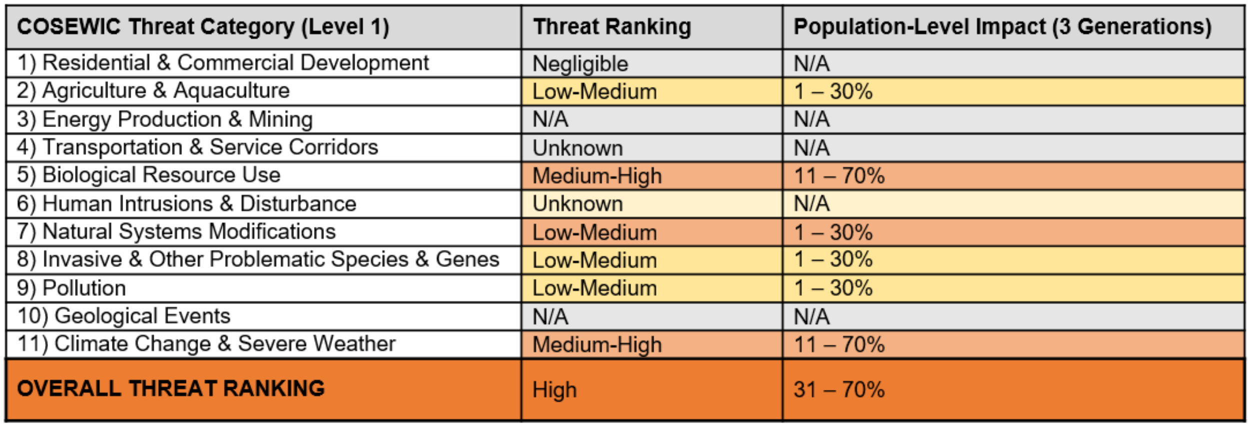
COSEWIC Threat Category (Level 1)	Threat Ranking	Population-Level Impact (3 Generations)
1) Residential & Commercial Development	Negligible	N/A
2) Agriculture & Aquaculture	Low-Medium	1 – 30%
3) Energy Production & Mining	N/A	N/A
4) Transportation & Service Corridors	Negligible	N/A
5) Biological Resource Use	Medium-High	11 – 70%
6) Human Intrusions & Disturbance	Low	1 – 10%
7) Natural Systems Modifications	Medium-High	11 – 70%
8) Invasive & Other Problematic Species & Genes	Low-Medium	1 – 30%
9) Pollution	Low-Medium	1 – 30%
10) Geological Events	Medium-High	11 – 70%
11) Climate Change & Severe Weather	Medium-High	11 – 70%
OVERALL THREAT RANKING	High-Extreme	31 – 100%

Figure 36. Summary of the threats assessment (Part 2 of RPA) for DU22 Taseko-ES. No stock-recruit data exists for DU22, therefore no quantitative analysis was conducted to determine the likelihood of this DU reaching its recovery targets.

7.9. DU24 WIDGEON-RT

DU24 is the only ocean-type DU assessed in this RPA. This DU has maintained low levels of abundance (≤1000 fish) throughout the time series, yet returns have been significantly lower than the historical average in most years since the late 1980s (exception 2009-2013). Sockeye from DU24 exhibit unique behaviour and habitat use compared to the other lake-rearing stocks considered in the RPA; they have the shortest migration distance to spawning grounds in Widgeon Slough, which is under tidal influence; they migrate out into the Strait of Georgia in their first summer as smaller-sized smolts; and they return to spawn primarily as 3 year old fish. As a result, DU24 is faced with a different suite of threats and limiting factors than the other DUs discussed above.

The threats assessment indicates this DU is at a High level of risk, particularly due to the low abundance, and that this is a single spawning site DU. Any major event that impacts spawning habitat may therefore have impacts on the DU. Due to the absence of stock-recruit data for DU24 no risk table is presented here; however, as stated in (DFO 2020a), using the other small stocks assessed in this report as proxies, **it is our recommendation that the only activities allowed that cause mortality are those that are in support of the survival and recovery of the species, and all sources of anthropogenic harm should be reduced to the maximum extent possible.**



COSEWIC Threat Category (Level 1)	Threat Ranking	Population-Level Impact (3 Generations)
1) Residential & Commercial Development	Negligible	N/A
2) Agriculture & Aquaculture	Low-Medium	1 – 30%
3) Energy Production & Mining	N/A	N/A
4) Transportation & Service Corridors	Unknown	N/A
5) Biological Resource Use	Medium-High	11 – 70%
6) Human Intrusions & Disturbance	Unknown	N/A
7) Natural Systems Modifications	Low-Medium	1 – 30%
8) Invasive & Other Problematic Species & Genes	Low-Medium	1 – 30%
9) Pollution	Low-Medium	1 – 30%
10) Geological Events	N/A	N/A
11) Climate Change & Severe Weather	Medium-High	11 – 70%
OVERALL THREAT RANKING	High	31 – 70%

Figure 37. Summary of the threats assessment (Part 2 of RPA) for DU24 Widgeon-RT. No stock-recruit data exists for DU24, therefore no quantitative analysis was conducted to determine the likelihood of this DU reaching its recovery targets.

7.10. CONCLUSIONS

The information presented in this RPA (Part 1 & 2) indicates that all FRS DUs considered are in serious peril, with the potential for several stocks to be extirpated in the next three generations (2021-2032; or next 10 years for DU24 Widgeon-RT) under current conditions. RPAs are designed to provide information as to whether harm to the species can be permitted under section 73 of SARA, and given the information presented here, it is apparent that all sources of anthropogenic harm should be minimized to give these stocks a chance to rebuild. However, as stated in (DFO 2014c), there may often be activities that are so localized in time or space and may potentially affect such a small proportion of the overall population that they may not amount to significant impacts at the population level. RPAs do not allocate harm to specific activities as this is a management decision that occurs outside of the RPA process (DFO 2014c); however, using the recovery plots presented in this section, it is possible to infer the potential risk of an activity if the impacts are quantifiable. For example, if an activity was identified that may lead to an additional 5% mortality on a DU, one could add this value to the current estimated ER for that DU, at current productivity (0%), to see how the predicted outcomes of reaching either recovery target has changed, keeping in mind that Recovery Target #1 better represents survival and Recovery Target #2 better represents actual recovery. While DFO Science will not determine what the acceptable level of risk is from an activity, it is noted the modelling work presented in DFO (2020) indicates it is either Unlikely or As Likely As Not for the majority of DUs to reach the lower Recovery Target #1 (removed from Endangered or Threatened status under COSEWIC) in the next three generations even in the most optimistic scenarios. This would suggest that any activity that further contributes to declines, or lowers the probability of a DU achieving recovery, is neither acceptable nor in the best interest of recovery for FRS.

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APPENDIX A. LIST OF WATERBODIES WITHIN FRS DUS (COSEWIC 2017)

DU2 Bowron-ES
• Antler Creek
• Bowron River
• Pomeroy Creek
• Huckey Creek
• Sus Creek
DU10 Harrison-L
• East Creek
• Weaver Channel
• Weaver Creek
DU14 North Barriere-ES
• Fennell Creek
• Harper Creek
DU16 Quesnel-S
• Abbott Creek
• Amos Creek
• Archie Creek
• Baxter Beach
• Bear Beach – shore,
• Betty Frank’s – shore
• Big Slide – shore
• Big Slide – shore 1km West
• Bill Miner Creek
• Bill Miner Creek – shore
• Bill Miner Creek – shore 3km Wes
• Blue Lead Creek
• Blue Lead Creek – shore
• Bouldery Creek
• Bouldery Creek – shore
• Bouldery Creek – shore 2km East
• Bowling Point
• Buckingham Creek
• Cameron Creek
• Clearbrook Creek
• Deception Point
• Devoe Creek
• Devoe Creek – shore
• Double T – shore
• East Arm – shore (Rock Slide – Penninsula Pt)
• East arm – unnamed creek 1
• East arm – unnamed creek 2 – shore
• East arm – unnamed point

- Elysia – shore
- Elysia – shore 1km West
- Franks Creek
- Franks Creek –shore
- Goose Creek
- Goose Point – shore
- Goose Point – shore 8km South
- Grain Creek
- Grain Creek – shore
- Hazeltine Creek
- Horsefly Channel
- Horsefly Lake
- Horsefly River
- Horsefly River – Above Falls
- Horsefly River – Lower
- Horsefly River – Upper
- Hurricane Point
- Isaiah Creek
- Junction Creek, Junction Creek – shore
- Killdog Creek
- Killdog Creek – shore
- Lester Shore
- Limestone Creek
- Limestone Point – shore
- Limestone Point – shore 5km South
- Little Horsefly River
- Logger Landing
- Long Creek
- Long Creek – shore
- Lynx Creek,
- Lynx Creek – shore
- Marten Creek
- Marten Creek – shore
- McKinley Creek,
- McKinley Creek – Lower
- McKinley Creek – Upper
- Mitchell River
- Moffat Creek
- Niagara Creek
- North Arm – shore (Bowling-Goose Pt.)
- North Arm – shore (Roaring-Deception Pt.)
- North Arm – unnamed cove
- Opa Beach

• Penfold Camp Shore
• Penfold Cree
• Quartz Point
• Quesnel Lake
• Raft Creek
• Roaring Point
• Roaring River
• Roaring River – shore
• Rock Slide
• Service Creek
• Slate Bay
• Slate Bay 1km East
• Spusks Creek
• Sue Creek
• Summit Creek
• Taku Creek
• Tasse Creek
• Tasse Creek – shore
• Tisdall Creek
• Trickle Creek
• Wasko Creek
• Wasko Creek – shore
• Watt Creek
• Watt Creek – shore
• Whiffle Creek
• Winkley Creek
DU17 Seton-L
• Portage Creek
DU20 Takla Trembleur-ES
• 5 Mile Creek
• 10 Mile Creek
• 15 Mile Creek
• 25 Mile Creek
• Ankwill Creek,
• Baptiste Creek
• Bates Creek
• Bivouac Creek
• Blackwater Creek
• Blanchette Creek
• Casamir Creek
• Consolidated Creek
• Crow Creek
• Driftwood River

• Dust Creek
• Felix Creek
• Fleming Creek
• Forfar Creek
• Forsythe Creek
• French Creek
• Frypan Creek
• Gluske Creek
• Hooker Creek
• Hudson Bay Creek
• Kastberg Creek
• Kazchek Creek
• Kotesine Creek
• Kynock Creek
• Leo Creek
• Lion Creek
• McDougall Creek
• Middle River (Rosette)
• Nancut Creek
• Narrows Creek
• Paula Creek
• Point Creek
• Porter Creet
• Rosette Creek
• Sakeniche River
• Sandpoint Creek
• Shale Creek
• Sinta Creek
• Takla Lake
• Tanezell Creek
• Tildesley Creek
• Tliti Creek
DU21 Takla Trembleur-S
• Kazchek Creek
• Kuzkwa Creek
• Middle River
• Pinchi Creek
• Sakeniche River
• Sowchea Creek
• Stuart Lake
• Stuart River
• Tachie River
DU22 Taseko-ES

• Taseko Lake
• Taseko River
DU24 Widgeon-RT
• Widgeon Slough • Widgeon Creek

APPENDIX B. COSEWIC THREATS TABLES

B.1. THREATS TABLES ASSESSORS

Dan Doutaz, Scott Decker, Ann-Marie Huang, Paul Grant, Pasan Samarasin, Tanya Vivian, David Patterson, Keri Benner, Dan Selbie, Lucas Pon, Chrys Neville, Justin Barbati, Paul Welch, Brittany Jenewein, Catherine Michielsens, Jamie Scroggie, Merran Hague, Jason Hwang, Eric Hertz, Eileen Jones, Pete Nicklin, Shamus Curtis, Marc Labelle, Mark Potyrala, Mike Staley

B.2. THREATS CALCULATOR RESULTS FOR DU2 – BOWRON ES

Table B.1. Overall Threat Impact DU2 Bowron ES

		Level 1 Threat Impact Counts	
Threat Impact		**high range**	**low range**
A	Very High	0	0
B	High	3	0
C	Medium	4	4
D	Low	1	4
Calculated Overall Threat Impact:		Very High	High

Assigned Overall Threat Impact: **AB = Very High - High**

Impact Adjustment Reasons: No Adjustment

Overall Threat Comments We assigned an overall impact rating of AB = Very High - High. This DU is in serious peril and is currently at very low abundance, and there is the potential for the stock to become extirpated in the next 3 generations, particularly following the Big Bar landslide. The main threats facing this population are landslides, climate change, ecosystems modifications, and fishing.

Table B.2. Threats Calculator Table DU2 Bowron ES

No.	**Threat**	**Impact (calculated)**		**Scope (next 10 Yrs.)**	**Severity (10 Yrs. or 3 Gen.)**	**Timing**	**Comments**
		Range	**Description**				
1	Residential & commercial development	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	-
1.1	Housing & urban areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	All Sockeye from this DU pass through the lower Fraser River (pervasive scope), but they transit the area rapidly and are unlikely to be greatly impacted by the footprint of new residential/urban developments. The footprint from these developments above the lower Fraser likely insignificant at the DU level. The group felt there likely are impacts but their severity is currently unknown.
1.2	Commercial & industrial areas	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	All Sockeye from this DU pass through the lower Fraser River (pervasive scope), but they transit the area rapidly and are therefore unlikely to be greatly impacted by new industrial or commercial developments. The footprint from these developments were thought to have a negligible impact at the population level
1.3	Tourism & recreation areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	All Sockeye from this DU pass through the lower Fraser where there is the highest concentration of tourism developments (boat launches, marinas, etc.; pervasive scope), yet the impacts are unknown. As with the other development categories these fish transit the lower Fraser rapidly and are not anticipated to be greatly impacted by the footprint of tourism development.
2	Agriculture & aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	-
2.1	Annual & perennial non-timber crops	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Annual and perennial non-timber crops are not anticipated to be major threat for this DU, as most of these activities occur in the lower Fraser where fish rapidly migrate through. A restricted portion of the population (11-30%) is expected to encounter these developments during outmigration or their return spawning migration, but likely has a slight impact at the DU level
2.2	Wood & pulp plantations	-	-	-	-	-	Not anticipated to be a threat - no footprints of wood/pulp plantations in Sockeye Salmon habitat
2.3	Livestock farming & ranching	-	-	-	-	-	Not anticipated to be a threat - spawning habitat within Provincial Park, no cattle grazing in this area

No.	Threat	Impact (calculated)		Scope (next 10 Yrs.)	Severity (10 Yrs. or 3 Gen.)	Timing	Comments
		Range	Description				
2.4	Marine & freshwater aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	**Fish Farms:** The physical footprint of aquaculture net-pens is not anticipated to be a threat to this DU. Other effects such as disease transmission is scored elsewhere. **Hatchery Competition:** Sockeye from this DU will experience competition with other salmon in the Pacific ocean (≈40% hatchery origin), including hatchery fish from BC, the U.S., Russia, and Japan. There are large salmon farming operations in the North Pacific that likely impact fish from this DU, but the impacts aren't well understood. The group cited a paper by Connors and a decrease in productivity, the following is taken from this paper: Connors et al (2020) reports from 2005 to 2015, the approximately 82 million adult Pink Salmon produced annually from hatcheries were estimated to have reduced the productivity of southern Sockeye Salmon by ~15%, on average. Additionally, Ruggerone and Connors (2015) report Pink Salmon abundance in the second year of Sockeye life at sea is a key factor contributing to the decline of Sockeye Salmon productivity. An increase from 200 to 400 million Pink Salmon in the North Pacific is predicted to reduce Fraser Sockeye recruitment by 39%. Length-at-age of Fraser Sockeye Salmon also declined with greater Sockeye and Pink Salmon abundance, and age at maturity increased with greater Pink Salmon abundance. Group also mentioned juvenile Sockeye en route to southern Alaska have diet/habitat overlap with Chum Salmon along the coast of BC.
3	Energy production & mining	-	-	-	-	-	-
3.1	Oil & gas drilling	-	-	-	-	-	Not anticipated to be a threat - in provincial park
3.2	Mining & quarrying	-	-	-	-	-	Not anticipated to be a threat, in Provincial Park. The group noted there are at least 3 placer mining tenures in the area, uncertainty if active or any effect (pollution and other effects scored elsewhere)
3.3	Renewable energy	-	-	-	-	-	Not anticipated to be a threat.
4	Transportation & service corridors	-	Negligible	Negligible (<1%)	Unknown	High (Continuing)	-
4.1	Roads & railroads	-	Negligible	Negligible (<1%)	Unknown	High (Continuing)	There are no roads in the upper watershed where spawning habitat is, a negligible number of fish may encounter road/railroad development but the impacts are unknown.
4.2	Utility & service lines	-	Negligible	Small (1-10%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs./3 gen)	Limited to expansion of Trans Mountain Pipeline in lower Fraser - these fish may be exposed to these activities in the near future (moderate timing), but the group felt a small portion of the population would likely be exposed. Given proper mitigations this is likely a negligible threat.
4.3	Shipping lanes	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	The lower Fraser is a highly active shipping lane, and dredging activities occur in this area. All fish are likely exposed to these activities (pervasive scope) but the impacts are unknown.
4.4	Flight paths	-	-	-	-	-	Not anticipated to be a threat.
5	Biological resource use	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	-
5.1	Hunting & collecting terrestrial animals	-	-	-	-	-	Not anticipated to be a threat.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs.)	Severity (10 Yrs. or 3 Gen.)	Timing	Comments
		Range	Description				
5.2	Gathering terrestrial plants	-	-	-	-	-	Not anticipated to be a threat.
5.3	Logging & wood harvesting	-	-	-	-	-	No timber harvesting within close proximity to streams. A large portion of the upper Bowron is within the park, don't see any logging near the lake or river. Once you get below Bowron Lake there is significant logging but this is just a migration corridor (other effects from temps etc. scored elsewhere)
5.4	Fishing & harvesting aquatic resources	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	We have seen returns in recent years below replacement, therefore any harvest can pose serious impact long-term. Average ER of 26% quoted between 2009-2016, although estimates are more uncertain for small stocks. These fish are among earlier-timed migrants into the river, so we would not expect high ERs, but don't have as good of protection for Bowron as we do for EStu. Bowron will get some protection from the EStu window closure in years where it is extended to 4 weeks, but this is not consistent. Ability to directly estimate ER for Bowron is affected by low abundance - it is included w/in a sub-group of Early Summers for assessment purposes, leading to increased uncertainty re: assessment of catch & run size in particular. stock is passively managed & information / assessment will be subject to higher uncertainty, and the actual ER outcomes more variable than for larger stocks. In early Shuswap dominant years U.S. directed fisheries will be trying to catch early Shuswap, and Bowron is in same timeframe. There is substantial interest to harvest Sockeye upstream in the Fraser by FN regardless of returns. FN have generally agreed with backing off EStu, yet there is debate every year on whether or not there will be extra protection of Bowron, Nadina, etc. This poses a substantial annual risk due to such low abundances. When there are warm water years management provides adjustments that play into allowable harm – fishing adjustments. The group felt 11-30% was appropriate for severity, with the acknowledgement that this is more likely in the upper range (30%).
6	Human intrusions & disturbance	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	-
6.1	Recreational activities	-	-	-	-	-	Not anticipated to be a threat - spawning areas in Provincial Park, likely no ATVs or UTVs in stream. Non-motorized access and no access to spawning habitat.
6.2	War, civil unrest & military exercises	-	-	-	-	-	Not anticipated to be a threat.
6.3	Work & other activities	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Handling stress at Big Bar and Whoosh system during upstream migration, although Whoosh has been decommissioned. Most activities are in the best interest of fish, but tagging stress still occurs as we are tagging fish to investigate passage. If fish are transported by truck there will be some mortality. Test fishing impacts when releasing fish - still within 1-10% range.
7	Natural system modifications	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	-
7.1	Fire & fire suppression	D	Low	Small (1-10%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	No recent fires of note, retain scores from DU21.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs.)	Severity (10 Yrs. or 3 Gen.)	Timing	Comments
		Range	Description				
7.2	Dams & water management/use	-	-	-	-	-	Not anticipated to be a threat.
7.3	Other ecosystem modifications	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	Similar rationale to DU20 (EStu) - mainstem Fraser likely the largest issue but the lower Bowron has had significant logging activity in the past and there can be additional hydrological impacts. This DU has a long migration at a high elevation, and the group felt serious to moderate (11-70%) was appropriate.
8	Invasive & other problematic species & genes	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	-
8.1	Invasive non-native/alien species	-	-	-	-	-	Not anticipated to be a threat.
8.2	Problematic native species	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	At lower abundances Sockeye populations can be significantly impacted by predation (Carl Walters quoted) - pinniped predation. If predator populations are going up there will likely be a concurrent increase in predation, however for pinnipeds, populations appear to be stable. Other marine (White-sided Dolphins) and terrestrial mammals (bears), avian predators (cormorants, mergansers, herons, eagles) were discussed, but question about them being out of balance due to human activities. Study quoted indicating higher predation on Sockeye with disease indicating fish being preyed on are in poor condition. Group felt that due to the low abundance this DU could have more than a slight impact, but due to the uncertainty with salmon/predator dynamics there could be potentially higher impacts. The group acknowledges this is not likely at the high end of the range (30%), but could potentially be higher than 10%.
8.3	Introduced genetic material	-	Unknown	Unknown	Unknown	High (Continuing)	Bowron have been taken for hatchery brood stock (first year 2020), genetic effects are unknown. Same rationale as Early Stu.
9	Pollution	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	-
9.1	Household sewage & urban waste water	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Fraser Sockeye are exposed to contaminants from many sources in freshwater, the Fraser estuary, and Strait of Georgia. These include PCBs, PCDs, metals, household pharmaceuticals, personal care products, pesticides, etc., particularly in the lower Fraser and estuary. We don't generally see direct mortality but pollution can lead to decreased productivity and fewer offspring through a variety of mechanisms. The group drew off previous work from the Fraser Chinook RPA, which indicated the threat is pervasive (71-100% exposed) and could potentially lead to declines ranging from 1-30%. The group agreed Chinook are more prone to the effects from pollution due to their life history, and the impacts on Sockeye would likely be less. There is considerable uncertainty surrounding the severity and there is less literature to draw off compared to Chinook, but the group agreed that the impacts could potentially be higher than 10%, but unlikely to be as high as a 30% population level decline. **This score was also given to subsequent categories 9.2 Industrial & military effluents, 9.3 Agricultural & forestry effluents, and 9.5 Air-borne pollution.**
9.2	Industrial & military effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs.)	Severity (10 Yrs. or 3 Gen.)	Timing	Comments
		Range	Description				
9.3	Agricultural & forestry effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste.
9.4	Garbage & solid waste	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	This includes micro plastics, abandoned fishing gear. The group felt that all Sockeye are exposed to microplastics, and some may encounter abandoned nets, however, there is currently insufficient information to determine severity.
9.5	Air-borne pollutants	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste.
9.6	Excess energy	-	Unknown	Unknown	Unknown	Unknown	Noise and excess light are considered here, although the scope/severity/timing is unknown.
10	Geological events	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	-
10.1	Volcanoes	-	-	-	-	-	Not anticipated to be a threat.
10.2	Earthquakes/tsunamis	-	-	-	-	-	Not anticipated to be a threat.
10.3	Avalanches/landslides	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	2019 was more extreme than 2020. The brood year escapement for 2020 was small, and the number of fish that returned was more than what we saw for the 2016 brood year escapement (i.e. 2012 return; could be differences in fisheries interceptions). Bowron was expected to be so infrequent in downstream samples in order to come up with credible number is challenging. Issue with sample sizes in lower Fraser. These fish could have had good success in the ocean, had good replacement but got wiped out by Big Bar. Conversely, marine survival could have been low and passage was better than expected. Depends on magnitude of freshet, window in terms of discharge is better. Lot of uncertainty, but impact can still be very high, we could see another year where most fish don't get through. 2019 case study - Nadina did very well for passage, Bowron did not. Opposite from what we would have expected. Uncertainty in timing confounding - beyond 70-100% is not realistic. There will be good years so 11-70 seems to be the most appropriate.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs.)	Severity (10 Yrs. or 3 Gen.)	Timing	Comments
		Range	Description				
11	Climate change & severe weather	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	-
11.1	Habitat shifting & alteration	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	Marine habitat: This includes sea level rise, ocean acidification, marine heatwaves/temperatures. Directed work by Jackie King highlighted. There has been another blob (marine heatwave), we've now seen the highest water temperatures in the Gulf of Alaska (GOA) in the last 50 years. This suggests these large changes are going to continue yet there is considerable uncertainty as to what the impact will be. Effects on growth in early marine period has an impact on survival of first winter. GOA surveys looking at fish condition after marine winter, however there are currently no results. We do know catches were not what we expected for age classes and we've seen poor returns. There have been better than expected returns for several stocks, and it was mentioned maybe marine survival problems have less effect. There was some question as to how different enumeration methods would lead to different results. Freshwater habitat: Earlier onset of freshet, high flows, temp effects. High discharge events are occurring more frequently as well as increases in long term temperature averages. Score: The group felt that all fish are exposed (pervasive 71-100%) but an uncertainty range of serious-moderate (11-70%) for severity was deemed appropriate. There was discussion of how some years will be worse than others, and there is the potential for this threat to exceed a 70% population level decline but is expected to be unlikely.
11.2	Droughts	-	-	-	-	-	Not anticipated to be a threat - group acknowledged drought may be a confounding factor to migration, but Bowron is in a wet area and likely not impacted by drought in next 3 generations.
11.3	Temperature extremes	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	Temperature extremes more likely to be an issue in the mainstem Fraser and lower Bowron than spawning habitat in upper watershed. Migration can be impacted by high temperatures, group agreed this was a moderate severity (11-30%). Similar rationale for large scope, on dominant run could potentially encounter more than 30% of run. Note: marine temp impacts scored in 11.1 Habitat shifting and alteration.
11.4	Storms & flooding	D	Low	Restricted - Small (1-30%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Group can't recall any major flooding events, some streams can flood but the watershed is intact (in Provincial Park) so we don't generally see high sediment pulses, channel destabilization, bedload movement, etc. Group felt that a major flood event could occur within the next 3 generations, and would likely have a slight severity (1-10% decline) on a small-restricted portion of the population (likely not at higher end of 30%).

Classification of Threats adopted from IUCN-CMP, Salafsky et al. (2008)

B.3. THREATS CALCULATOR RESULTS FOR DU10 HARRISON (U/S)-L

Table B.3. Overall Threat Impact – DU10 Harrison (U/S)-L

		Level 1 Threat Impact Counts	
Threat Impact		high range	low range
A	Very High	0	0
B	High	2	0
C	Medium	4	2
D	Low	0	4
Calculated Overall Threat Impact:		Very High	High

Assigned Overall Threat Impact: **B = High**

Impact Adjustment Reasons: -

Overall Threat Comments We assigned an overall impact rating of B = High. This was reduced from AB = Very High - High, as the group felt that while there are some substantial threats facing this DU, the high abundance does not suggest this population is in danger of going extinct in the next 3 generations. The primary threats facing this DU are climate change, pollution, and fishing.

Table B.4. Threats Calculator Table DU10 Harrison (U/S)-L

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
1	Residential & commercial development	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	-
1.1	Housing & urban areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	All Sockeye from this DU pass through the lower Fraser River (pervasive scope), but they transit the area rapidly and are unlikely to be greatly impacted by the footprint of new residential/urban developments. The footprint from these developments above the lower Fraser likely insignificant at the DU level. The group felt there likely are impacts but their severity is currently unknown.
1.2	Commercial & industrial areas	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	All Sockeye from this DU pass through the lower Fraser River (pervasive scope), but they transit the area rapidly and are therefore unlikely to be greatly impacted by new industrial or commercial developments. The lower Fraser River is highly developed and the remaining habitat is currently more prone to industrial development than housing. The footprint from these developments were thought to have a negligible impact at the population level.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
1.3	Tourism & recreation areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	All Sockeye from this DU pass through the lower Fraser where there is the highest concentration of tourism developments (boat launches, marinas, etc.; pervasive scope), yet the impacts are unknown. As with the other development categories these fish transit the lower Fraser rapidly and are not anticipated to be greatly impacted by the footprint of tourism development.
2	Agriculture & aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	-
2.1	Annual & perennial non-timber crops	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Annual and perennial non-timber crops are not anticipated to be a major threat for this DU, as most of these activities occur in the lower Fraser where fish rapidly migrate through. A restricted portion of the population (11-30%) is expected to encounter these developments during outmigration or their return spawning migration, but likely has a slight impact at the DU level.
2.2	Wood & pulp plantations	-	-	-	-	-	Not anticipated to be a threat
2.3	Livestock farming & ranching	-	-	-	-	-	Not anticipated to be a threat - no cattle in spawning area or lake
2.4	Marine & freshwater aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	**Fish Farms:** The physical footprint of aquaculture net-pens is not anticipated to pose a threat to FRS. Other effects such as disease transmission is scored elsewhere. **Hatchery Competition:** Sockeye from this DU will experience competition with other salmon in the Pacific ocean (≈40% hatchery origin), including hatchery fish from BC, the U.S., Russia, and Japan. There are large salmon farming operations in the North Pacific that likely impact fish from this DU, but the impacts aren't well understood. The group cited a paper by Connors and a decrease in productivity, the following is taken from this paper: Connors et al (2020) reports from 2005 to 2015, the approximately 82 million adult Pink Salmon produced annually from hatcheries were estimated to have reduced the productivity of southern Sockeye Salmon by ~15%, on average. Additionally, Ruggerone and Connors (2015) report Pink Salmon abundance in the second year of Sockeye life at sea is a key factor contributing to the decline of Sockeye Salmon productivity. An increase from 200 to 400 million Pink Salmon in the North Pacific is predicted to reduce Fraser Sockeye recruitment by 39%. Length-at-age of Fraser Sockeye salmon also declined with greater Sockeye and Pink Salmon abundance, and age at maturity increased with greater Pink Salmon abundance. Group also mentioned juvenile Sockeye en route to southern Alaska have diet/habitat overlap with Chum Salmon along the coast of BC.
3	Energy production & mining	-	-	-	-	-	-
3.1	Oil & gas drilling	-	-	-	-	-	Not anticipated to be a threat
3.2	Mining & quarrying	-	-	-	-	-	Not anticipated to be a threat
3.3	Renewable energy	-	-	-	-	-	Not anticipated to be a threat
4	Transportation & service corridors	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	-

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
4.1	Roads & railroads	-	Unknown	Small (1-10%)	Unknown	High (Continuing)	Roads in area, but new development unlikely in DU area. Likely a small portion of the population encounters road development, but the severity is unknown (could potentially be beneficial because of upgrades to culverts, etc.).
4.2	Utility & service lines	-	Negligible	Small (1-10%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Limited to expansion of Transmountain Pipeline in lower Fraser - these fish may be exposed to these activities in the near future (moderate timing), but the group felt a small portion of the population would likely be exposed. Given proper mitigations this is likely a negligible threat.
4.3	Shipping lanes	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	The lower Fraser is a highly active shipping lane, and dredging activities occur in this area. All fish are likely exposed to these activities (pervasive scope) but the impacts are unknown.
4.4	Flight paths	-	-	-	-	-	N/A
5	Biological resource use	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	-
5.1	Hunting & collecting terrestrial animals	-	-	-	-	-	Not anticipated to be a threat
5.2	Gathering terrestrial plants	-	-	-	-	-	Not anticipated to be a threat
5.3	Logging & wood harvesting	-	-	-	-	-	Log dumps at north end, no salvage logging, should not have an effect for Sockeye.
5.4	Fishing & harvesting aquatic resources	BC	High - Medium	Pervasive (71-100%)	Serious – Moderate (11-70%)	High (Continuing)	Group agreed fishing impacts similar to Portage - a moderate severity threat (11-30%) but the upper range should be increased to 70%, as on dominant years for late Sockeye is intercepted in addition to high Pink abundance years (caught as bycatch) bringing exploitation over 30%. It is unlikely the severity is near the upper range (70%). Should not see major harvest on 3 out of 4 years.
6	Human intrusions & disturbance	-	Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	-
6.1	Recreational activities	-	-	-	-	-	Not anticipated to be a threat
6.2	War, civil unrest & military exercises	-	-	-	-	-	Not anticipated to be a threat
6.3	Work & other activities	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	Spawning channel - potential interception for tagging with Harrison M.R. program. A portion will miss Harrison program due to slight differences in timing. Maybe affect 31-70% of fish. Chum and Chinook work intercepts fish as well.
7	Natural system modifications	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	-
7.1	Fire & fire suppression	-	-	-	-	-	Lake shoreline has been prone to fires, Weaver can burn, but not anticipated to be significant due to the large size of lake and DU area.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
7.2	Dams & water management/use	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Flood control structures on Weaver intended to ensure adequate water levels during egg incubation, potentially mitigates flash flooding (positive benefit). Prevents fish from moving up past channel, although if it was not there there would be no spawning.
7.3	Other ecosystem modifications	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	This DU is less threatened than many of the other DUs as the spawning area is in the lower Fraser, therefore the group agreed moderate-slight was appropriate for severity.
8	Invasive & other problematic species & genes	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	-
8.1	Invasive non-native/alien species	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Juvenile Sockeye potentially exposed to predation by Spiny Rays (particularly bass). Upstream migration from Weaver into Harrison lake may expose juveniles to predation (clear water, slackwater).
8.2	Problematic native species	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	At lower abundances Sockeye populations can be significantly impacted by predation (Carl Walters quoted) - pinniped predation. If predator populations are going up there will likely be a concurrent increase in predation, however for pinnipeds, populations appear to be stable. Other marine (White-sided Dolphins) and terrestrial mammals (bears), avian predators (cormorants, mergansers, herons, eagles) were discussed, but question about them being out of balance due to human activities. Study quoted indicating higher predation on Sockeye with disease indicating fish being preyed on are in poor condition. Group felt that due to the low abundance this DU could have more than a slight impact, but due to the uncertainty with salmon/predator dynamics there could be potentially higher impacts. there is a year-round seal colony on the Harrison; arguably they may be out of balance due to log sorting creating haul out habitat; still a lot of uncertainty. The group acknowledges this is not likely at the high end of the range (30%), but could potentially be higher than 10%.
8.3	Introduced genetic material	-	-	-	-	-	Hatchery release in 2018, group unsure of plans to continue. Unlikely to happen again in future, no score.
9	Pollution	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	-

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
9.1	Household sewage & urban waste water	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	Fraser Sockeye are exposed to contaminants from many sources in freshwater, the Fraser estuary, and Strait of Georgia. These include PCBs, PCDs, metals, household pharmaceuticals, personal care products, pesticides, etc., particularly in the lower Fraser and estuary. We don't generally see direct mortality but pollution can lead to decreased productivity and fewer offspring through a variety of mechanisms. The group drew off previous work from the Fraser Chinook RPA, which indicated the threat is pervasive (71-100% exposed) and could potentially lead to declines ranging from 1-30%. The group agreed Chinook are more prone to the effects from pollution due to their life history, and the impacts on Sockeye would likely be less. There is considerable uncertainty surrounding the severity and there is less literature to draw off compared to Chinook, but the group agreed that the impacts could potentially be higher than 10%, but unlikely to be as high as a 30% population level decline. **This score was also given to subsequent categories 9.2 Industrial & military effluents, 9.3 Agricultural & forestry effluents, and 9.5 Air-borne pollution.**
9.2	Industrial & military effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.3	Agricultural & forestry effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.4	Garbage & solid waste	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	This includes micro plastics, abandoned fishing gear. The group felt that all Sockeye are exposed to microplastics, and some may encounter abandoned nets, however, there is currently insufficient information to determine severity.
9.5	Air-borne pollutants	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.6	Excess energy	-	Unknown	Unknown	Unknown	Unknown	Noise and excess light are considered here, although the scope/severity/timing is unknown.
10	Geological events	-	Negligible	Negligible(<1%)	Serious (31-70%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	-
10.1	Volcanoes	-	-	-	-	-	Not anticipated to be a threat
10.2	Earthquakes/ tsunamis	-	-	-	-	-	Not anticipated to be a threat
10.3	Avalanches/ landslides	-	Negligible	Negligible(<1%)	Serious (31-70%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Meagre Creek landslide - some indication that Meagre creek had significant impacts but currently unknown. This landslide created a large sediment plume at the north end of Lillooet Lake that moved south into Harrison Lake over the next year where juveniles from this DU rear. Sockeye DUs that rear in these lakes exhibited poor survival in the years following this landslide.
11	Climate change & severe weather	BC	High - Medium	Pervasive (71-100%)	Serious – Moderate (11-70%)	High (Continuing)	-

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
11.1	Habitat shifting & alteration	BC	High - Medium	Pervasive (71-100%)	Serious – Moderate (11-70%)	High (Continuing)	**Marine habitat:** This includes sea level rise, ocean acidification, marine heatwaves/temperatures. Directed work by Jackie King highlighted. There has been another blob (marine heatwave), we've now seen the highest water temperatures in the Gulf of Alaska (GOA) in the last 50 years. This suggests these large changes are going to continue yet there is considerable uncertainty as to what the impact will be. Effects on growth in early marine period has an impact on survival of first winter. GOA surveys looking at fish condition after marine winter, however there are currently no results. We do know catches were not what we expected for age classes and we've seen poor returns. There have been better than expected returns for several stocks, and it was mentioned maybe marine survival problems have less effect. There was some question as to how different enumeration methods would lead to different results. **Freshwater habitat:** Earlier onset of freshet, high flows, temp effects. High discharge events are occurring more frequently as well as increases in long term temperature averages. **Score:** The group felt that all fish are exposed (pervasive 71-100%) but an uncertainty range of serious-moderate (11-70%) for severity was deemed appropriate. There was discussion of how some years will be worse than others, and there is the potential for this threat to exceed a 70% population level decline but is expected to be unlikely.
11.2	Droughts	D	Low	Restricted (11-30%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Late summer drought can cause access problems for this DU, suspected to be moderate timing. Store water upstream of spawning channel, restrict flows downstream. First part of run negatively affected, not whole populations. Slight impact suspected, restricted portion exposed (11-30%).
11.3	Temperature extremes	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	Weaver Creek and Morris Lake experiences high temperatures and low dissolved oxygen issues (anoxic). Morris issue is only on high abundance years, timing impacts them differently. Early timed fish most impacted, and there have been shifts in timing. In previous years fences have been installed to prevent fish from entering. Group felt impacts should be similar to Portage.
11.4	Storms & flooding	D	Low	Small (1-10%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Portion of population that spawns in Weaver Creek itself would be most impacted, likely less than 10%.

Classification of Threats adopted from IUCN-CMP, Salafsky et al. (2008)

B.4. THREATS CALCULATOR RESULTS FOR DU14 NORTH BARRIERE-ES

Table B.5. Overall Threat Impact – DU14 North Barriere-ES

		Level 1 Threat Impact Counts	
Threat Impact		**high range**	**low range**
A	Very High	0	0
B	High	2	0
C	Medium	4	3
D	Low	0	3
Calculated Overall Threat Impact:		Very High	High

Assigned Overall Threat Impact: **AB = Very High - High**

Impact Adjustment Reasons: No Adjustment

Overall Threat Comments This DU was assigned a threat impact of Very-High - High. This is a de novo poulation and DU has had highly variable abundance through time, yet recent trends indicate this DU is in peril. The primary threats to this DU are climate change, pollution, ecosystems modifications, and fishing.

Table B.6. Threats Calculator Table DU14 North Barriere-ES

No.	**Threat**	**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
		Range	**Description**				
1	Residential & commercial development	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	-
1.1	Housing & urban areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	All Sockeye from this DU pass through the lower Fraser River (pervasive scope), but they transit the area rapidly and are unlikely to be greatly impacted by the footprint of new residential/urban developments. The footprint from these developments above the lower Fraser likely insignificant at the DU level. The group felt there likely are impacts but their severity is currently unknown.
1.2	Commercial & industrial areas	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	All Sockeye from this DU pass through the lower Fraser River (pervasive scope), but they transit the area rapidly and are therefore unlikely to be greatly impacted by new industrial or commercial developments. The lower Fraser River is highly developed and the remaining habitat is currently more prone to industrial development than housing. The footprint from these developments were thought to have a negligible impact at the population level.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
1.3	Tourism & recreation areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	All Sockeye from this DU pass through the lower Fraser where there is the highest concentration of tourism developments (boat launches, marinas, etc.; pervasive scope), yet the impacts are unknown. As with the other development categories these fish transit the lower Fraser rapidly and are not anticipated to be greatly impacted by the footprint of tourism development.
2	Agriculture & aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	-
2.1	Annual & perennial non-timber crops	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Annual and perennial non-timber crops are not anticipated to be major threat for this DU, as most of these activities occur in the lower Fraser where fish rapidly migrate through. A restricted portion of the population (11-30%) is expected to encounter these developments during outmigration or their return spawning migration, but likely has a slight impact at the DU level.
2.2	Wood & pulp plantations	-	-	-	-	-	Not anticipated to be a threat
2.3	Livestock farming & ranching	-	-	-	-	-	Not anticipated to be a threat
2.4	Marine & freshwater aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	**Fish Farms:** The physical footprint of aquaculture net-pens is not anticipated to pose a threat to FRS. Other effects such as disease transmission is scored elsewhere. **Hatchery Competition:** Sockeye from this DU will experience competition with other salmon in the Pacific ocean (≈40% hatchery origin), including hatchery fish from BC, the U.S., Russia, and Japan. There are large salmon farming operations in the North Pacific that likely impact fish from this DU, but the impacts aren't well understood. The group cited a paper by Connors and a decrease in productivity, the following is taken from this paper: Connors et al (2020) reports from 2005 to 2015, the approximately 82 million adult Pink Salmon produced annually from hatcheries were estimated to have reduced the productivity of southern Sockeye salmon by ~15%, on average. Additionally, Ruggerone and Connors (2015) report Pink Salmon abundance in the second year of Sockeye life at sea is a key factor contributing to the decline of Sockeye Salmon productivity. An increase from 200 to 400 million Pink Salmon in the North Pacific is predicted to reduce Fraser Sockeye recruitment by 39%. Length-at-age of Fraser Sockeye Salmon also declined with greater Sockeye and Pink Salmon abundance, and age at maturity increased with greater Pink Salmon abundance. Group also mentioned juvenile Sockeye en route to southern Alaska have diet/habitat overlap with Chum Salmon along the coast of BC.
3	Energy production & mining	-	-	-	-	-	-
3.1	Oil & gas drilling	-	-	-	-	-	Not anticipated to be a threat
3.2	Mining & quarrying	-	-	-	-	-	Harper mine, exploration plans for large mine in Saskum Creek (flows into Fennel). Coal mining increases in future in N. Thompson area. Group did not have enough information to score this threat.
3.3	Renewable energy	-	-	-	-	-	Not anticipated to be a threat
4	Transportation & service corridors		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	-

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
4.1	Roads & railroads	-	Unknown	Large (31-70%)	Unknown	High (Continuing)	This system has been extensively logged, quite a few roads in area. Large increase in coal transport. Group felt large scope, unknown impact.
4.2	Utility & service lines	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Expansion of pipline along North Thompson, no crossings but along migratory corridor. Likely negligible impacts.
4.3	Shipping lanes	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	The lower Fraser is a highly active shipping lane, and dredging activities occur in this area. All fish are likely exposed to these activities (pervasive scope) but the impacts are unknown.
4.4	Flight paths	-	-	-	-	-	N/A
5	Biological resource use	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	-
5.1	Hunting & collecting terrestrial animals	-	-	-	-	-	Not anticipated to be a threat
5.2	Gathering terrestrial plants	-	-	-	-	-	Not anticipated to be a threat
5.3	Logging & wood harvesting	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Extensive logging in Barriere watershed, active logging operations. Group felt there was potential for in-stream impacts, likely a low-level threat to a restricted portion of the population.
5.4	Fishing & harvesting aquatic resources	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	Similar rationale to Quesnel - Years that fisheries are targeting late Shuswap fish there could be additional impacts. Chilko is a key driver for harvest, could lead to higher impacts on high-pressure years. There is considerable uncertainty in the severity, and while the group agrees it could potentially be higher than 30% it is unlikely to be at the high end of the range (70%).
6	Human intrusions & disturbance	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	-
6.1	Recreational activities	-	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Some jet boat use in north Thompson, boating/recreation in North Barriere Lake, likely not ATVs/UTVs in spawning grounds as DU is surrounded by thick vegetation. Likely negligible threat.
6.2	War, civil unrest & military exercises	-	-	-	-	-	Not anticipated to be a threat
6.3	Work & other activities	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Foot surveys only within this DU, likely a negligible impact - similar to Bowron or Early Stu.
7	Natural system modifications	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	-
7.1	Fire & fire suppression	D	Low	Small (1-10%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Massive wildefires in this area in recent past, not much left to burn. Could potentially occur in the future, moderate timing was agreed upon. Aerial bucketing from lake occurs but not expected to be a threat.
7.2	Dams & water management/use	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Some water extraction in lower Barriere system, but there are 3 lakes that buffer effects. No dams, limited to flood control structures. Not an issue for spawning area. Group feels this is negligible severity.
7.3	Other ecosystem modifications	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	The Thompson drainage has been significantly altered from forestry and wildfires, the group agreed moderate severity was appropriate.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
8	Invasive & other problematic species & genes	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	-
8.1	Invasive non-native/alien species	-	-	-	-	-	Not anticipated to be a threat
8.2	Problematic native species	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	Anticipated to be less of a threat to Sockeye when compared to Chinook, due to limited residence time in the lower Fraser River and the Strait of Georgia. At lower abundances Sockeye populations can be significantly impacted by predation (Carl Walters quoted). If predator populations are going up there will likely be a concurrent increase in predation, however for pinnipeds, populations appear to be stable. Other marine (White-sided Dolphins) and terrestrial mammals (bears), avian predators (cormorants, mergansers, herons, eagles) were discussed, but question about them being out of balance due to human activities. Study quoted indicating higher predation on Sockeye with disease indicating fish being preyed on are in poor condition, although there was disagreement with the group. **Unique to this DU:** Range of Pink Salmon increasing, probably not a current issue in lower area, but there is the potential for expansion. Group does not feel Pink will move into upper section in next 3 generations so score was not altered.
8.3	Introduced genetic material	-	-	-	-	-	Group unaware of any future plans for enhancement - de novo population
9	Pollution	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	-
9.1	Household sewage & urban waste water	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	Fraser Sockeye are exposed to contaminants from many sources in freshwater, the Fraser estuary, and Strait of Georgia. These include PCBs, PCDs, metals, household pharmaceuticals, personal care products, pesticides, etc., particularly in the lower Fraser and estuary. We don't generally see direct mortality but pollution can lead to decreased productivity and fewer offspring through a variety of mechanisms. The group drew off previous work from the Fraser Chinook RPA, which indicated the threat is pervasive (71-100% exposed) and could potentially lead to declines ranging from 1-30%. The group agreed Chinook are more prone to the effects from pollution due to their life history, and the impacts on Sockeye would likely be less. There is considerable uncertainty surrounding the severity and there is less literature to draw off compared to Chinook, but the group agreed that the impacts could potentially be higher than 10%, but unlikely to be as high as a 30% population level decline. **This score was also given to subsequent categories 9.2 Industrial & military effluents, 9.3 Agricultural & forestry effluents, and 9.5 Air-borne pollution.**
9.2	Industrial & military effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	Potential increased threat of pollution from North Thompson coal transport and pipeline, group did not feel it was appropriate to change score - see 9.1 Household sewage & urban waste.
9.3	Agricultural & forestry effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.4	Garbage & solid waste	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	This includes micro plastics, abandoned fishing gear. The group felt that all Sockeye are exposed to microplastics, and some may encounter abandoned nets, however, there is currently insufficient information to determine severity.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
9.5	Air-borne pollutants	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.6	Excess energy	-	Unknown	Unknown	Unknown	Unknown	Noise and excess light are considered here, although the scope/severity/timing is unknown.
10	Geological events	-	-	-	-	-	-
10.1	Volcanoes	-	-	-	-	-	Not anticipated to be a threat
10.2	Earthquakes/tsunamis	-	-	-	-	-	Not anticipated to be a threat
10.3	Avalanches/landslides	-	-	-	-	-	Group can't think of a major landslide in recent history, no evidence this will happen in this DU. Flat valley surrounding spawning.
11	Climate change & severe weather	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	-
11.1	Habitat shifting & alteration	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	**Marine habitat:** This includes sea level rise, ocean acidification, marine heatwaves/temperatures. Directed work by Jackie King highlighted. There has been another blob (marine heatwave), we've now seen the highest water temperatures in the Gulf of Alaska (GOA) in the last 50 years. This suggests these large changes are going to continue yet there is considerable uncertainty as to what the impact will be. Effects on growth in early marine period has an impact on survival of first winter. GOA surveys looking at fish condition after marine winter, however there are currently no results. We do know catches were not what we expected for age classes and we've seen poor returns. There have been better than expected returns for several stocks, and it was mentioned maybe marine survival problems have less effect. There was some question as to how different enumeration methods would lead to different results. **Freshwater habitat:** Earlier onset of freshet, high flows, temp effects. High discharge events are occurring more frequently as well as increases in long term temperature averages. **Score:** The group felt that all fish are exposed (pervasive 71-100%) but an uncertainty range of serious-moderate (11-70%) for severity was deemed appropriate. There was discussion of how some years will be worse than others, and there is the potential for this threat to exceed a 70% population level decline but is expected to be unlikely.
11.2	Droughts	-	-	-	-	-	Relatively stable from drought perspective - buffered by several lakes.
11.3	Temperature extremes	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	Group feels the score should be similar to Taseko - temp extremes buffered from large streams and lakes, impacts just from mainstem Fraser River.
11.4	Storms & flooding	D	Low	Restricted – Small (1-30%)	Moderate – Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Due to fire activity there could be flood events, group unaware of any major storm events in recent years.

Classification of Threats adopted from IUCN-CMP, Salafsky et al. (2008)

B.5. THREATS CALCULATOR RESULTS FOR DU16 QUESNEL-S

Table B.7. Overall Threat Impact – DU16 Quesnel-S

		Level 1 Threat Impact Counts	
Threat Impact		high range	low range
A	Very High	0	0
B	High	2	1
C	Medium	5	3
D	Low	1	4
Calculated Overall Threat Impact:		Very High	Very High

Assigned Overall Threat Impact: **B = High**

Impact Adjustment Reasons: Adjusted down to High due to large number of fish and recent population trends; management expected to adjust based on abundance.

Overall Threat Comments This DU was assigned a ranking of B = High. The ranking was adjusted down from A = Very High as this is one of the highest abundance DUs and is not anticipated to go extinct within the next 3 generations. There are, however, many threats facing this DU that can lead to significant population level declines, including climate change, landslides (Big Bar), pollution, ecosystems modification, and fishing. There are also unknown impacts from the recent Mount Polley tailings pond breach, but they are anticipated to be negative.

Table B.8. Threats Calculator Table DU16 Quesnel-S

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
1	Residential & commercial development	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	-
1.1	Housing & urban areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	All Sockeye from this DU pass through the lower Fraser River (pervasive scope), but they transit the area rapidly and are unlikely to be greatly impacted by the footprint of new residential/urban developments. The footprint from these developments above the lower Fraser likely insignificant at the DU level. The group felt there likely are impacts but their severity is currently unknown.
1.2	Commercial & industrial areas	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	All Sockeye from this DU pass through the lower Fraser River (pervasive scope), but they transit the area rapidly and are therefore unlikely to be greatly impacted by new industrial or commercial developments. The footprint from these developments were thought to have a negligible impact at the population level.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
1.3	Tourism & recreation areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	All Sockeye from this DU pass through the lower Fraser where there is the highest concentration of tourism developments (boat launches, marinas, etc.; pervasive scope), yet the impacts are unknown. As with the other development categories these fish transit the lower Fraser rapidly and are not anticipated to be greatly impacted by the footprint of tourism development.
2	Agriculture & aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	-
2.1	Annual & perennial non-timber crops	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	This DU has the highest concentration of agricultural activity in the Horsefly area, and the group felt the impacts are likely higher than the other DUs.
2.2	Wood & pulp plantations	-	-	-	-	-	Not anticipated to be a threat - no new footprints of wood/pulp plantations in Sockeye Salmon habitat.
2.3	Livestock farming & ranching	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Horsefly system has substantial ranching, unlike most other DUs - cattle will likely be in-river. To what extent the group is not sure but will be higher than other DUs.
2.4	Marine & freshwater aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	**Fish Farms:** The physical footprint of aquaculture net-pens is not anticipated to be a threat to this DU. Other effects such as disease transmission is scored elsewhere. **Hatchery Competition:** Sockeye from this DU will experience competition with other salmon in the Pacific ocean (≈40% hatchery origin), including hatchery fish from BC, the U.S., Russia, and Japan. There are large salmon farming operations in the North Pacific that likely impact fish from this DU, but the impacts aren't well understood. The group cited a paper by Connors and a decrease in productivity, the following is taken from this paper: Connors et al (2020) reports from 2005 to 2015, the approximately 82 million adult Pink Salmon produced annually from hatcheries were estimated to have reduced the productivity of southern Sockeye salmon by ~15%, on average. Additionally, Ruggerone and Connors (2015) report Pink Salmon abundance in the second year of Sockeye life at sea is a key factor contributing to the decline of Sockeye Salmon productivity. An increase from 200 to 400 million Pink Salmon in the North Pacific is predicted to reduce Fraser Sockeye recruitment by 39%. Length-at-age of Fraser Sockeye Salmon also declined with greater Sockeye and Pink Salmon abundance, and age at maturity increased with greater Pink Salmon abundance. Group also mentioned juvenile Sockeye en route to southern Alaska have diet/habitat overlap with Chum Salmon along the coast of BC.
3	Energy production & mining	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	-
3.1	Oil & gas drilling	-	-	-	-	-	Not anticipated to be a threat - no new oil/gas drilling is expected to occur directly in Sockeye habitat.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
3.2	Mining & quarrying		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	One of the world's largest mining disasters occurred in this DU - 25 million cubic meters (or more) of mine tailings were discharged into Quesnel lake making large accumulations of tailings/materials (7km2 at lake bottom). Threats from this include sediment transport issues, water quality issues, smothering effects, pollution, changes in food web dynamics, biological responses, etc. Loss of habitat in Hazeltine Creek - this habitat typically used only in large return years. There will likely be lingering habitat effects from the disaster and without dredging material out there will be permanent damage. Published paper cited looking at "greening" effects in years following event. All fish pass through this corridor of the lake. There is abundant evidence there have been negative effects from Mount Polley, yet the severity of impacts is currently unknown.
3.3	Renewable energy	-	-	-	-	-	Not anticipated to be a threat - the footprint of wind, tidal, and solar power activities is not expected to occur in Sockeye habitat.
4	Transportation & service corridors	-	Unknown	Large (31-70%)	Unknown	High (Continuing)	-
4.1	Roads & railroads	-	Unknown	Large (31-70%)	Unknown	High (Continuing)	Roads are particularly abundant in the Horsefly area, not so much in the Mitchell River area. Many logging roads. The proportion of Horsefly Sockeye is larger than the Mitchell so a large portion of the population likely encounters road development, yet the severity is unknown. With proper planning and mitigations in place the impacts from road developments are likely insignificant or even potentially beneficial (i.e. road and culvert improvement).
4.2	Utility & service lines	-	Negligible	Small(1-10%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Limited to expansion of Transmountain Pipeline in lower Fraser - these fish may be exposed to these activities in the near future (moderate timing), but the group felt a small portion of the population would likely be exposed. Given proper mitigations this is likely a negligible threat.
4.3	Shipping lanes	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	The lower Fraser is a highly active shipping lane, and dredging activities occur in this area. All fish are likely exposed to these activities (pervasive scope) but the impacts are unknown.
4.4	Flight paths	-	-	-	-	-	N/A
5	Biological resource use	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	-
5.1	Hunting & collecting terrestrial animals	-	-	-	-	-	Not anticipated to be a threat
5.2	Gathering terrestrial plants	-	-	-	-	-	Not anticipated to be a threat
5.3	Logging & wood harvesting	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Not many major fires around the Quesnel area, most of the burns happened west of the DU. Also not much in the way of pest infestations within the DU so salvage logging operations are unlikely. The group felt a restricted portion of the population could be exposed but the impacts are likely slight in severity.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
5.4	Fishing & harvesting aquatic resources	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	Due to the return migration timing of this DU the group felt impacts would be similar to late Stuart (DU21; only a few days difference in timing). Exploitation similar to Late Stuart as well (38% Quesnel, 35% Late Stuart/Stellako - averages from 2009-2016 but high variability across years). Years that fisheries are targeting late Shuswap fish there could be additional impacts. The Horsefly and Mitchell components of this DU are variable and which group dominates the run will influence impacts. Mitchell later than Horsefly - Horsefly timing may be similar but generally later timed than LStu, likely higher ER due to fisheries targeting Late run Sockeye. This DU is less exposed to in-river fishing impacts compared to other upstream DUs. Chilko is a key driver for harvest, could lead to higher impacts on high-pressure years. There is considerable uncertainty in the severity, and while the group agrees it could potentially be higher than 30% it is unlikely to be at the high end of the range (70%).
6	Human intrusions & disturbance	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	-
6.1	Recreational activities	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	ATVs/UTVs can access some of these systems and potentially impact habitat (particularly Horsefly/McKinley areas). Jet boat activity in the Mitchell river was also identified as a threat. A potentially large portion of the population could be exposed to impacts from recreational activities, but the severity is anticipated to be slight.
6.2	War, civil unrest & military exercises	-	-	-	-	-	Not anticipated to be a threat
6.3	Work & other activities	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Big Bar - tagging is expected to continue for several years. Could also include spawning channel impacts. Scope should drop from others. Over the next 12 years or so there will likely be less interactions with research activities, group felt restricted was a more appropriate scope. Severity still 1-10%. A diversion fence has been identified to hold fish up in the past but recent modifications have reduced these impacts. Spawning channel operation an annual decision, and there are impacts when it runs. Group agrees 11-30% is reasonable.
7	Natural system modifications	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	-
7.1	Fire & fire suppression	D	Low	Small (1-10%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	There is the potential for a fire to impact this DU in the near future (moderate timing), but a small portion of the population will likely be exposed with slight impacts. The stream systems within thie DU are in general large and relatively buffered from direct impacts of wildfires.
7.2	Dams & water management/use	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	There is flow regulation on McKinlie Lake - this is actually a potential benefit if managed properly - intent was to reduce water temps in horsefly to minimize impacts to fish. Intensive Horsefly water extraction. Slight severity chosen.
7.3	Other ecosystem modifications	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	Similar in score to many other DUs that spawn in the mid-upper Fraser drainage.
8	Invasive & other problematic species & genes	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	-

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
8.1	Invasive non-native/alien species	-	-	-	-	-	Quesnel system has invasive bass, carp, potentially others in addition to lower Fraser invasive species. Scope, severity and timing currently unknown.
8.2	Problematic native species	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	Anticipated to be less of a threat to Sockeye when compared to Chinook, due to limited residence time in the lower Fraser River and the Strait of Georgia. At lower abundances Sockeye populations can be significantly impacted by predation (Carl Walters quoted). If predator populations are going up there will likely be a concurrent increase in predation, however for pinnipeds, populations appear to be stable. Other marine (White-sided Dolphins) and terrestrial mammals (bears), avian predators (cormorants, mergansers, herons, eagles) were discussed, but not out of balance due to human activities compared to pinnipeds. Study quoted indicating higher predation on Sockeye with disease, indicating fish being preyed on are in poor condition.
8.3	Introduced genetic material	-	Unknown	Unknown	Unknown	High - Moderate	Operation of spawning channel - holding fish up and forcing them to spawn may have genetic effects. In past there was a diversion fence, earlier timed portion was supposed to spawn in upper but were diverted into channel. Fence is now a partial diversion, spawning channel does not operate every year (not in years of large returns).
9	Pollution	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	-
9.1	Household sewage & urban waste water	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	Fraser Sockeye are exposed to contaminants from many sources in freshwater, the Fraser estuary, and Strait of Georgia. These include PCBs, PCDs, metals, household pharmaceuticals, personal care products, pesticides, etc., particularly in the lower Fraser and estuary. We don't generally see direct mortality but pollution can lead to decreased productivity and fewer offspring through a variety of mechanisms. The group drew off previous work from the Fraser Chinook RPA, which indicated the threat is pervasive (71-100% exposed) and could potentially lead to declines ranging from 1-30%. The group agreed Chinook are more prone to the effects from pollution due to their life history, and the impacts on Sockeye would likely be less. There is considerable uncertainty surrounding the severity and there is less literature to draw off compared to Chinook, but the group agreed that the impacts could potentially be higher than 10%, but unlikely to be as high as a 30% population level decline. **This score was also given to subsequent categories 9.2 Industrial & military effluents, 9.3 Agricultural & forestry effluents, and 9.5 Air-borne pollution.**
9.2	Industrial & military effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste. Group discussion of Mount Polley disaster. Potential growth impacts - juveniles in west arm grew a lot larger than normal, high density in response to spill. Haven't seen that since then. Huge influence of nutrients, potentially on food web in west arm. No justification to alter scores, however severity could be potentially higher.
9.3	Agricultural & forestry effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.4	Garbage & solid waste	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	This includes micro plastics, abandoned fishing gear. The group felt that all Sockeye are exposed to microplastics, and some may encounter abandoned nets, however, there is currently insufficient information to determine severity.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
9.5	Air-borne pollutants	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.6	Excess energy	-	Unknown	Unknown	Unknown	Unknown	Noise and excess light are considered here, although the scope/severity/timing is unknown.
10	Geological events	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	-
10.1	Volcanoes	-	-	-	-	-	Not anticipated to be a threat
10.2	Earthquakes/ tsunamis	-	-	-	-	-	Not anticipated to be a threat
10.3	Avalanches /landslides	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	Similar impacts to late Stuart (DU21), maintain moderate impacts as these fish migrate upstream past Big Bar.
11	Climate change & severe weather	B	High	Pervasive (71-100%)	Serious (31-70%)	High (Continuing)	-
11.1	Habitat shifting & alteration	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	**Marine habitat:** This includes sea level rise, ocean acidification, marine heatwaves/temperatures. Directed work by Jackie King highlighted. There has been another blob (marine heatwave), we've now seen the highest water temperatures in the Gulf of Alaska (GOA) in the last 50 years. This suggests these large changes are going to continue yet there is considerable uncertainty as to what the impact will be. Effects on growth in early marine period has an impact on survival of first winter. GOA surveys looking at fish condition after marine winter, however there are currently no results. We do know catches were not what we expected for age classes and we've seen poor returns. There have been better than expected returns for several stocks, and it was mentioned maybe marine survival problems have less effect. There was some question as to how different enumeration methods would lead to different results. **Freshwater habitat:** This DU is likely to be less affected by freshwater habitat shifting/alteration compared to EStu, however the group felt that given the uncertainty in the marine environment, paired with increasing frequency of discharge/temperature events, the severity of serious-moderate (11-70%) was appropriate, with the acknowledgement this is unlikely at the high end of the range (70%).
11.2	Droughts	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	This area is prone to drought, low water high temperatures. Frequent low water and high temp in Horsefly during spawning, system prone to high pre-spawn mortality. Timing changed to high due to frequency. The proportion of fish exposed is potentially near the high end of this range (70%).
11.3	Temperature extremes	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	Same justification as DU21 - less severe impacts than EStu population due to their later migration timing and the buffering effects of the larger spawning streams and lake-headed systems. Temp extremes could affect the same proportion of population in the event of a dominant year return (31-70% scope). The group agreed 11-30% severity was appropriate.
11.4	Storms & flooding	D	Low	Restricted – Small (1-30%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Storms and flooding, rain on snow events occur, scores deemed appropriate.

Classification of Threats adopted from IUCN-CMP, Salafsky et al. (2008)

B.6. THREATS CALCULATOR RESULTS FOR DU17 SETON-L

Table B.9. Overall Threat Impact DU17 Seton-L

Threat Impact		Level 1 Threat Impact Counts	
		high range	low range
A	Very High	0	0
B	High	3	1
C	Medium	4	3
D	Low	1	4
Calculated Overall Threat Impact:		Very High	Very High

Assigned Overall Threat Impact: **A = Very High**

Impact Adjustment Reasons: Not adjusted

Overall Threat Comments We assigned an overall impact rating of A = Very High. This is a single spawning site DU that spawns above Seton hydro dam, and there has been a recent landslide that has significantly impacted habitat. Additionally, these Sockeye return late and can be intercepted during the middle Shuswap fishery. This DU is also experiencing shifts in return migration timing potentially exposing them to additional impacts. There is the potential for this DU to go extinct in the next 3 generations if the threats facing this DU are not reduced.

Table B.10. Threats Calculator Table DU17 Seton-L

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
1	Residential & commercial development	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	-
1.1	Housing & urban areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	All Sockeye from this DU pass through the lower Fraser River (pervasive scope), but they transit the area rapidly and are unlikely to be greatly impacted by the footprint of new residential/urban developments. The footprint from these developments above the lower Fraser likely insignificant at the DU level. The group felt there likely are impacts but their severity is currently unknown.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
1.2	Commercial & industrial areas	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	All Sockeye from this DU pass through the lower Fraser River (pervasive scope), but they transit the area rapidly and are therefore unlikely to be greatly impacted by new industrial or commercial developments. The lower Fraser River is highly developed and the remaining habitat is currently more prone to industrial development than housing. The footprint from these developments were thought to have a negligible impact at the population level.
1.3	Tourism & recreation areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	All Sockeye from this DU pass through the lower Fraser where there is the highest concentration of tourism developments (boat launches, marinas, etc.; pervasive scope), yet the impacts are unknown. As with the other development categories these fish transit the lower Fraser rapidly and are not anticipated to be greatly impacted by the footprint of tourism development.
2	Agriculture & aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	-
2.1	Annual & perennial non-timber crops	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Annual and perennial non-timber crops are not anticipated to be major threat for this DU, as most of these activities occur in the lower Fraser where fish rapidly migrate through. A restricted portion of the population (11-30%) is expected to encounter these developments during outmigration or their return spawning migration, but likely has a slight impact at the DU level.
2.2	Wood & pulp plantations	-	-	-	-	-	Not anticipated to be a threat
2.3	Livestock farming & ranching	-	-	-	-	-	Potentially cattle on migratory route, but not in spawning habitat. Group agreed not a threat.
2.4	Marine & freshwater aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	**Fish Farms:** The physical footprint of aquaculture net-pens is not anticipated to pose a threat to FRS. Other effects such as disease transmission is scored elsewhere. **Hatchery Competition:** Sockeye from this DU will experience competition with other salmon in the Pacific ocean (≈40% hatchery origin), including hatchery fish from BC, the U.S., Russia, and Japan. There are large salmon farming operations in the North Pacific that likely impact fish from this DU, but the impacts aren't well understood. The group cited a paper by Connors and a decrease in productivity, the following is taken from this paper: Connors et al (2020) reports from 2005 to 2015, the approximately 82 million adult Pink Salmon produced annually from hatcheries were estimated to have reduced the productivity of southern Sockeye salmon by ~15%, on average. Additionally, Ruggerone and Connors (2015) report Pink Salmon abundance in the second year of Sockeye life at sea is a key factor contributing to the decline of Sockeye Salmon productivity. An increase from 200 to 400 million Pink Salmon in the North Pacific is predicted to reduce Fraser Sockeye recruitment by 39%. Length-at-age of Fraser Sockeye Salmon also declined with greater Sockeye and Pink Salmon abundance, and age at maturity increased with greater Pink Salmon abundance. Group also mentioned juvenile Sockeye en route to southern Alaska have diet/habitat overlap with Chum Salmon along the coast of BC.
3	Energy production & mining	-	-	-	-	-	-

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
3.1	Oil & gas drilling	-	-	-	-	-	Not anticipated to be a threat
3.2	Mining & quarrying	-	-	-	-	-	Not anticipated to be a threat
3.3	Renewable energy	-	-	-	-	-	Not anticipated to be a threat
4	Transportation & service corridors	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	-
4.1	Roads & railroads	-	Unknown	Small (1-10%)	Unknown	High (Continuing)	Some road development around lake shore, unknown impact but only expected to affect small portion (<10%) of population.
4.2	Utility & service lines	-	Negligible	Small (1-10%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Limited to expansion of Transmountain Pipeline in lower Fraser - these fish may be exposed to these activities in the near future (moderate timing), but the group felt a small portion of the population would likely be exposed. Given proper mitigations this is likely a negligible threat.
4.3	Shipping lanes	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	The lower Fraser is a highly active shipping lane, and dredging activities occur in this area. All fish are likely exposed to these activities (pervasive scope) but the impacts are unknown.
4.4	Flight paths	-	-	-	-	-	N/A
5	Biological resource use	BC	High - Medium	Pervasive (71-100%)	Serious – Moderate (11-70%)	High (Continuing)	-
5.1	Hunting & collecting terrestrial animals	-	-	-	-	-	Not anticipated to be a threat
5.2	Gathering terrestrial plants	-	-	-	-	-	Not anticipated to be a threat
5.3	Logging & wood harvesting	-	-	-	-	-	Not anticipated to be a threat
5.4	Fishing & harvesting aquatic resources	BC	High - Medium	Pervasive (71-100%)	Serious – Moderate (11-70%)	High (Continuing)	Group agreed this was a moderate severity threat (11-30%) but the upper range should be increased to 70%, as on dominant years for late Sockeye is intercepted in addition to high Pink abundance years (caught as bycatch) bringing exploitation over 30%. It is unlikely the severity is near the upper range (70%).
6	Human intrusions & disturbance	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	-
6.1	Recreational activities	-	-	-	-	-	Rafting in areas but limited impacts, not scored
6.2	War, civil unrest & military exercises	-	-	-	-	-	Not anticipated to be a threat
6.3	Work & other activities	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	There is considerable work done in this system at Seton Dam. Downstream smolt handling/processing, tagging being done on juveniles currently. Downstream Big Bar tagging impacts Seton Sockeye. Additional juvenile component may have impacts.
7	Natural system modifications	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	-
7.1	Fire & fire suppression	-	-	-	-	-	No recent fires in area, spawning habitat within rural area therefore direct fire impacts are unlikely.
7.2	Dams & water management/use	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	Seton Dam. Main issue is fish finding way into fishway, radio tagging studies showed number of fish that couldn't locate fishway (need to also consider tagging effects). Study on Gates indicates impacts, likely not as

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
							high for Portage. Early return timing might be a result of changes in abundance.
7.3	Other ecosystem modifications	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	This DU spawns within a highly modified ecosystem - extensive hydroelectric development. There are likely significant impacts to this DU in addition to mainstem Fraser impacts.
8	Invasive & other problematic species & genes	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	-
8.1	Invasive non-native/alien species	-	-	-	-	-	Not anticipated to be a threat
8.2	Problematic native species	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	Anticipated to be less of a threat to Sockeye when compared to Chinook, due to limited residence time in the lower Fraser River and the Strait of Georgia. At lower abundances Sockeye populations can be significantly impacted by predation (Carl Walters quoted). If predator populations are going up there will likely be a concurrent increase in predation, however for pinnipeds, populations appear to be stable. Other marine (White-sided Dolphins) and terrestrial mammals (bears), avian predators (cormorants, mergansers, herons, eagles) were discussed, but question about them being out of balance due to human activities. Study quoted indicating higher predation on Sockeye with disease indicating fish being preyed on are in poor condition.
8.3	Introduced genetic material	-	Unknown	Unknown	Unknown	High (Continuing)	Dispersal from populations above Big Bar going into Seton system. Confirmed adults have gone into system, not sure if they have spawned or not. Potential genetic effects from dispersal of other Late-run stocks, impacts unknown.
9	Pollution	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	-
9.1	Household sewage & urban waste water	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	Fraser Sockeye are exposed to contaminants from many sources in freshwater, the Fraser estuary, and Strait of Georgia. These include PCBs, PCDs, metals, household pharmaceuticals, personal care products, pesticides, etc., particularly in the lower Fraser and estuary. We don't generally see direct mortality but pollution can lead to decreased productivity and fewer offspring through a variety of mechanisms. The group drew off previous work from the Fraser Chinook RPA, which indicated the threat is pervasive (71-100% exposed) and could potentially lead to declines ranging from 1-30%. The group agreed Chinook are more prone to the effects from pollution due to their life history, and the impacts on Sockeye would likely be less. There is considerable uncertainty surrounding the severity and there is less literature to draw off compared to Chinook, but the group agreed that the impacts could potentially be higher than 10%, but unlikely to be as high as a 30% population level decline. **This score was also given to subsequent categories 9.2 Industrial & military effluents, 9.3 Agricultural & forestry effluents, and 9.5 Air-borne pollution.**
9.2	Industrial & military effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
9.3	Agricultural & forestry effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.4	Garbage & solid waste	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	This includes micro plastics, abandoned fishing gear. The group felt that all Sockeye are exposed to microplastics, and some may encounter abandoned nets, however, there is currently insufficient information to determine severity.
9.5	Air-borne pollutants	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.6	Excess energy	-	Unknown	Unknown	Unknown	Unknown	Noise and excess light are considered here, although the scope/severity/timing is unknown.
10	Geological events	B	High	Pervasive (71-100%)	Serious (31-70%)	High (Continuing)	-
10.1	Volcanoes	-	-	-	-	-	Not anticipated to be a threat
10.2	Earthquakes/tsunamis	-	-	-	-	-	Not anticipated to be a threat
10.3	Avalanches/landslides	B	High	Pervasive (71-100%)	Serious (31-70%)	High (Continuing)	Whitecap Creek - In September 2015 a debris flood and channel avulsion occurred on Whitecap Creek that deposited large amounts of sediment into Portage River, resulting in a complete blockage for approximately 170 m that prevented outflow from Anderson Lake and caused flooding around the lakeshore (BGC 2018). The following year in November 2016, another channel avulsion occurred in Whitecap Creek that resulted in an approximate 75% blockage of Portage River (BGC 2018). These events occurred in high quality spawning habitat and there are no alternate spawning grounds in the DU.
11	Climate change & severe weather	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	-
11.1	Habitat shifting & alteration	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	**Marine habitat:** This includes sea level rise, ocean acidification, marine heatwaves/temperatures. Directed work by Jackie King highlighted. There has been another blob (marine heatwave), we've now seen the highest water temperatures in the Gulf of Alaska (GOA) in the last 50 years. This suggests these large changes are going to continue yet there is considerable uncertainty as to what the impact will be. Effects on growth in early marine period has an impact on survival of first winter. GOA surveys looking at fish condition after marine winter, however there are currently no results. We do know catches were not what we expected for age classes and we've seen poor returns. There have been better than expected returns for several stocks, and it was mentioned maybe marine survival problems have less effect. There was some question as to how different enumeration methods would lead to different results. **Freshwater habitat:** Earlier onset of freshet, high flows, temp effects. High discharge events are occurring more frequently as well as increases in long term temperature averages. **Score:** The group felt that all fish are exposed (pervasive 71-100%) but an uncertainty range of serious-moderate (11-70%) for severity was deemed appropriate. There was discussion of how some years will be worse than others, and there is the potential for this threat to exceed a 70% population level decline but is expected to be unlikely.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
11.2	Droughts	-	-	-	-	-	This DU spawns in a system buffered by large lakes from drought effects
11.3	Temperature extremes	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	Later run timing of this DU don't get exposed to temperature extremes (for the most part), the earliest fish coming in in August could be affected by temp extremes . Earlier migration timing may expose them. Moderate severity agreed upon.
11.4	Storms & flooding						Moderate timing, small-restricted portion of population exposed (1-30%). 75% spawning habitat below Whitecap Creek (caused by storms), larger portion of this population will be exposed as there is limited habitat. When Whitecap flooded it backed up all the way to Anderson Lake, led to large sediment inputs. The expected increase in storms and floods in the Fraser Basin can lead to the increased prevalence of landslides

Classification of Threats adopted from IUCN-CMP, Salafsky et al. (2008)

B.7. THREATS CALCULATOR RESULTS FOR DU20 TAKLA-TREMBLEUR ESTU

Table B.11. Overall Threat Impact DU20 Takla-Trembleur EStu

		Level 1 Threat Impact Counts	
Threat Impact		high range	low range
A	Very High	1	1
B	High	2	1
C	Medium	4	1
D	Low	1	5
Calculated Overall Threat Impact:		Very High	Very High

Assigned Overall Threat Impact: **A = Very High**

Impact Adjustment Reasons: No Adjustment

Overall Threat Comments This DU was assigned a ranking of A = Very High. The group agreed there is the potential for this DU to go extinct in the next 3 generations. This is the most threatened Fraser Sockeye DU: they have the longest migration to reach spawning grounds; they have the earliest migration timing and are highly sensitive to shifting hydrologic conditions; the Big Bar landslide has resulted in major pre-spawn mortality and continues to pose issues to passage. The primary threats facing this DU are climate change, landslides (Big Bar), ecosystems modifications, pollution, and fishing.

Table B.12. Threats Calculator Table DU20 Takla-Trembleur EStu

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
1	Residential & commercial development	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	-
1.1	Housing & urban areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	All Sockeye from this DU pass through the lower Fraser River, but they transit the area rapidly and are therefore unlikely to be affected by new residential developments. There are also no proposed developments of this type in the mainstem Fraser or within the Stuart drainage that are anticipated to have an impact on this DU.
1.2	Commercial & industrial areas	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	All Sockeye from this DU pass through the lower Fraser River, but they transit the area rapidly and are therefore unlikely to be affected by new industrial or commercial developments. There are also no proposed developments of this type in the mainstem Fraser or within the Stuart drainage that are anticipated to have an impact on this DU.
1.3	Tourism & recreation areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	All Sockeye from this DU pass through the lower Fraser River, but they transit the area rapidly and are therefore unlikely to be affected by new tourism or recreational developments. There are also no proposed developments of this type in the mainstem Fraser or within the Stuart drainage that are anticipated to have an impact on this DU.
2	Agriculture & aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	-
2.1	Annual & perennial non-timber crops	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Annual and perennial non-timber crops are not anticipated to be major threat for this DU, as most of these activities occur in the lower Fraser where fish rapidly migrate through. A restricted portion of the population (11-30%) is expected to encounter these developments during outmigration or their return spawning migration, but likely has a slight impact at the DU level.
2.2	Wood & pulp plantations	-	-	-	-	-	Not anticipated to be a threat - no footprints of wood/pulp plantations in Sockeye salmon habitat.
2.3	Livestock farming & ranching		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	There is little in the way of cattle ranching in the Stuart drainage, and the streams are generally too deep for cattle to transit. It is therefore unlikely there will be in-river impacts from cattle trampling or habitat degradation from cattle.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
2.4	Marine & freshwater aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	**Fish Farms:** The physical footprint of aquaculture net-pens is not anticipated to pose a threat to FRS. Other effects such as disease transmission is scored elsewhere. **Hatchery Competition:** Sockeye from this DU will experience competition with other salmon in the Pacific ocean (≈40% hatchery origin), including hatchery fish from BC, the U.S., Russia, and Japan. High production of Chum and Pink in Japan and Russia. There are large salmon farming operations in the North Pacific that likely impact fish from this DU, but the impacts aren't well understood. The group cited a paper by Connors and a decrease in productivity, the following is taken from this paper: Connors et al (2020) reports from 2005 to 2015, the approximately 82 million adult Pink Salmon produced annually from hatcheries were estimated to have reduced the productivity of southern Sockeye salmon by ~15%, on average. Additionally, Ruggerone and Connors (2015) report Pink Salmon abundance in the second year of Sockeye life at sea is a key factor contributing to the decline of Sockeye Salmon productivity. An increase from 200 to 400 million Pink Salmon in the North Pacific is predicted to reduce Fraser Sockeye recruitment by 39%. Length-at-age of Fraser Sockeye Salmon also declined with greater Sockeye and Pink Salmon abundance, and age at maturity increased with greater Pink Salmon abundance. Group also mentioned juvenile Sockeye en route to southern Alaska have diet/habitat overlap with Chum Salmon along the coast of BC.
3	Energy production & mining	-	-	-	-	-	-
3.1	Oil & gas drilling	-	-	-	-	-	Not anticipated to be a threat - no in-river impacts from oil and gas drilling anticipated directly in Fraser Sockeye habitat (pollution and other associated impacts scored elsewhere).
3.2	Mining & quarrying	-	-	-	-	-	Not anticipated to be a threat - gravel extraction likely not an issue as these fish transit the lower Fraser River quickly, and do not rely on this habitat enough to be impacted. No one knew of any placer mining in the Stuart drainage, therefore the direct impacts from these activities are likely to be neglible (pollution and other associated impacts scored elsewhere). Mention of mine, leaching - look into this.
3.3	Renewable energy	-	-	-	-	-	Not anticipated to be a threat - footprint from solar, tidal, wind energy not anticipated to encroach on Fraser Sockeye habitat.
4	Transportation & service corridors	-	Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	-
4.1	Roads & railroads	-	Unknown	Small (1-10%)	Unknown	High (Continuing)	Not many roads in this area, with proper mitigation impacts will likely be neglible. Small portion of population subject to road development, severity unknown. Railway, passage issues at crossings.
4.2	Utility & service lines	-	Negligible	Small (1-10%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Transmountain pipline expansion in lower Fraser was raised, group felt that even if a small portion of the population was exposed to expansion activities the effects would likely be neglible.
4.3	Shipping lanes	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Dredging activities and log storage in the in the lower Fraser River are not anticipated to impact this DU, as they rapidly migrate through the area, timing of dredging activities is misaligned.
4.4	Flight paths	-	-	-	-	-	N/A

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
5	Biological resource use	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	-
5.1	Hunting & collecting terrestrial animals	-	-	-	-	-	Not anticipated to be a threat
5.2	Gathering terrestrial plants	-	-	-	-	-	Not anticipated to be a threat
5.3	Logging & wood harvesting	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	There is logging in the Stuart drainage, no salvage logging in this area from fires/pest infestations, no in-river logging that may affect these DUs.
5.4	Fishing & harvesting aquatic resources	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	Early Stuart DU is protected by a window closure, which more strict management/protection compared to that experiened by other Sockeye DUs. 3-4 week window closure and there is no authorized fishing during this time. Our harvest goals aim for less than 10%, however, there is concern that the actual mortality rates could be higher than estimated due to management uncertainty, illegal fishing activities, bycatch mortality, etc. Collecting fish for hatchery enhancement activities was identified as a significant source of removals for this DU. However, the actual impact on future populations will depend on the location of broodstock collection (e.g. spawning grounds vs Big Bar) and conditions in specific years. For example, fish taken for broodstock in 2020 from Big Bar likely wouldn't have made it to spawning grounds to contribute to future generations. The need for collection of brood stock, however, will vary from year to year and the long-term impacts are unknown. Due to the disagreement about being less than 10% exploitation, the uncertainty range of 1-30 was chosen for severity with the acknowledgement that it is unlikely to be at the low end (1%), but also not likely to be as high as 30%. It was noted that with Big Bar, if productivity is below replacement over several generations removals could lead to more serious declines.
6	Human intrusions & disturbance	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	-
6.1	Recreational activities	D	Low	Small(1-10%)	Slight (1-10%)	High (Continuing)	Can't drive ATVs or UTVs through most of these streams, but possible for some. Foot traffic in-stream not likely.
6.2	War, civil unrest & military exercises		-	-	-	-	Not anticipated to be a threat
6.3	Work & other activities	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Handling stress at Big Bar and Whoosh system during upstream migration, although Whoosh has been decommissioned. Most activities are in the best interest of fish, but tagging stress still occurs as we are tagging fish to investigate passage. If fish are transported by truck there will be some mortality. Test fishing impacts when releasing fish (some disagreement as no test fishing this early) - still within 1-10% range.
7	Natural system modifications	BC	High - Medium	Pervasive (71-100%)	Serious – Moderate (11-70%)	High (Continuing)	-

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
7.1	Fire & fire suppression	D	Low	Small (1-10%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	There have been several major fires in the Stuart watershed, but the majority has been unaffected by fire. There are currently no fires in the drainage but we expect some of it to burn in future years, and within the next 3 generations (moderate timing). East side of watershed is much more dry and recovery would take longer in this area. If there is a large fire there would be an impact on thermal regimes of the streams in this DU, but the Stuart is a large watershed, and a fire will likely affect a small portion of the overall DU area.
7.2	Dams & water management/use	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	No lower Fraser River impacts from flood control structures. Kemano dam water releases may have some impact on fish from this DU -exposure to lower flows and higher temperatures. With proper mitigations in place these impacts are likely less then 10%, but agreed upon by the group to be more than 1%.
7.3	Other ecosystem modifications	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	Forestry, wildfires, agriculture and development are known to impact stream temperature and flow regimes due to increases in impervious surfaces. Sockeye from DU20 are dependent on spring freshet for their migration, high flows can lead to mortality down as far down as the lower Fraser. Sockeye are more vulnerable to high flows and temperatures than Chinook salmon, therefore previous scores could be comparable. There has been high in-river mortality prior to Big Bar (60% quoted in workshop), and with Big Bar as high as 90%. The group felt that all fish from this DU are affected, but there is considerable uncertainty as to what the severity is. The group felt that moderate (11-30%) was insufficient, therefore an uncertainty range of moderate-serious (11-70%) with the acknowledgement that it is unlikely at the high end (70%).
8	Invasive & other problematic species & genes	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	-
8.1	Invasive non-native/alien species	-	-	-	-	-	Not anticipated to be a threat
8.2	Problematic native species	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	Anticipated to be less of a threat to Sockeye when compared to Chinook, due to limited residence time in the lower Fraser River and the Strait of Georgia. At lower abundances Sockeye populations can be significantly impacted by predation (Carl Walters quoted). If predator populations are going up there will likely be a concurrent increase in predation, however for pinnipeds, populations appear to be stable. Other marine (White-sided Dolphins) and terrestrial mammals (bears), avian predators (cormorants, mergansers, herons, eagles) were discussed, but question about them being out of balance due to human activities. Study quoted indicating higher predation on Sockeye with disease indicating fish being preyed on are in poor condition, although there was disagreement with the group. Increases in kokanee in Takla Lake could be a potential issue. Low abundances of this DU, paired with high abundances of kokanee may be a force impacting fish, although there is low certainty. Bears are a more significant threat to this DU, the majority of these Sockeye spawn in very small streams and are easily accessible to bears. Stock Assessment crews regularly note high predator impacts on the small number of Sockeye that are making it to the spawning grounds. May be more than a limiting factor. Severity for this DU could be near the high end of range (30%).

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
8.3	Introduced genetic material	-	Unknown	Unknown	Unknown	High (Continuing)	Considerable work has been done since Big Bar landslide occurred. An increased proportion of the population will likely be subject to genetic effects in future years.
9	Pollution	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	-
9.1	Household sewage & urban waste water	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	Fraser Sockeye are exposed to contaminants from many sources in freshwater, the Fraser estuary, and Strait of Georgia. These include PCBs, PCDs, metals, household pharmaceuticals, personal care products, pesticides, etc., particularly in the lower Fraser and estuary. We don't generally see direct mortality but pollution can lead to decreased productivity and fewer offspring through a variety of mechanisms. The group drew off previous work from the Fraser Chinook RPA, which indicated the threat is pervasive (71-100% exposed) and could potentially lead to declines ranging from 1-30%. The group agreed Chinook are more prone to the effects from pollution due to their life history, and the impacts on Sockeye would likely be less. There is considerable uncertainty surrounding the severity and there is less literature to draw off compared to Chinook, but the group agreed that the impacts could potentially be higher than 10%, but unlikely to be as high as a 30% population level decline. **This score was also given to subsequent categories 9.2 Industrial & military effluents, 9.3 Agricultural & forestry effluents, and 9.5 Air-borne pollution.**
9.2	Industrial & military effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.3	Agricultural & forestry effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.4	Garbage & solid waste	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	This includes micro plastics, abandoned fishing gear. The group felt that all Sockeye are exposed to microplastics, and some may encounter abandoned nets, however, there is currently insufficient information to determine severity.
9.5	Air-borne pollutants	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.6	Excess energy	-	Unknown	Unknown	Unknown	Unknown	Noise and excess light are considered here, although the scope/severity/timing is unknown.
10	Geological events	A	Very High	Pervasive (71-100%)	Extreme (71-100%)	High (Continuing)	-
10.1	Volcanoes	-	-	-	-	-	Not anticipated to be a threat
10.2	Earthquakes/ tsunamis	-	-	-	-	-	Not anticipated to be a threat

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
10.3	Avalanches/ landslides	A	Very High	Pervasive (71-100%)	Extreme (71-100%)	High (Continuing)	Sockeye from this DU spawn above Big Bar and there have been major losses as a result, and multiple generations will encounter the landslide. This DU has the earliest migration timing and is most impacted. If the slide is not resolved in the short term this will likely lead to extirpation of this DU. There are numerous other locations along the mainstem Fraser where a major landslide could occur (FIND REFS), so could also happen again within the next few generations. There is considerable uncertainty surrounding the impacts but the group felt that a severity of extreme was appropriate given recent migration mortality (98-99%), although this is likely not all attributed to the landslide. This will be a chronic problem at the site for multiple years.
11	Climate change & severe weather	B	High	Pervasive (71-100%)	Serious (31-70%)	High (Continuing)	-
11.1	Habitat shifting & alteration	BC	High - Medium	Pervasive (71-100%)	Serious – Moderate (11-70%)	High (Continuing)	**Marine habitat:** This includes sea level rise, ocean acidification, marine heatwaves/temperatures. Directed work by Jackie King highlighted. There has been another blob (marine heatwave), we've now seen the highest water temperatures in the Gulf of Alaska (GOA) in the last 50 years. This suggests these large temperature changes are going to continue yet there is considerable uncertainty as to what the impact will be. Effects on growth in early marine period has an impact on survival of first winter. GOA surveys looking at fish condition after marine winter, however there are currently no results. We do know catches were not what we expected for age classes and we've seen poor returns. There have been better than expected returns for several stocks in different systems along the coast in the same year as we've seen decreased returns for Fraser Sockeye, so the declines in productivity observed in Fraser Sockeye are unlikely to be entirely due to changes in marine conditions (and it was mentioned maybe marine survival problems have less effect). There was some question as to how different enumeration methods would lead to different results. **Freshwater habitat:** This DU is going to be the most impacted by changes in shifting freshwater habitat (i.e. earlier onset of freshet, high flows). High discharge events are occurring more frequently as well as increases in long term temperature averages. On good years migration mortality as low as 40%, 70% on years with high temperatures, and up to 90% with recent high discharge years. Nechako study cited showing persistent and ongoing water temperature issues, seen as a negative stressor. **Score:** The group felt that all fish are exposed (pervasive 71-100%) but an uncertainty range of serious-moderate (11-70%) for severity was deemed appropriate. There was discussion of how some years will be worse than others, and there is the potential for this threat to exceed a 70% population level decline but is expected to be unlikely.
11.2	Droughts	-	Negligible	Large (31-70%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Droughts are not anticipated to be an every-year event, although they will continue to happen and evidence suggests they will occur with increasing frequency in the future (moderate timing chosen). If a dominant year experiences drought a large portion of population can be affected, but will not be 100% due to different cohorts existing simultaneously in freshwater and the ocean (large scope 31-70%). Severity was thought to be negligible as juveniles emerging from gravel and move into lakes during a time where impacts will likely occur. Even on low water years most fish can reach spawning grounds.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
11.3	Temperature extremes	B	High	Large (31-70%)	Serious (31-70%)	High (Continuing)	Temperature extremes can lead to significant migration mortality, particularly during high discharge years. EStu has the highest ATU of all Fraser Sockeye stocks while actively migrating – rapid migration, no holding, longest distance. These fish experience their highest temperatures once they enter the Nechako system, which is impacted by Kemano Dam. Fraser river expected to increase in temperature in future years. Historically has not been a significant issue, but is definitely increasing. These fish have adapted for particular temperatures, with increasing levels this will become a more problematic issue. Cold temperature extremes have also been observed in Takla with anchor ice formation which can impact incubation succes. The group felt the severity could be higher than 31%, but unlikely to be in the high range (70%)
11.4	Storms & flooding	D	Low	Restricted – Small (1-30%)	Moderate – Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Considerable flooding – occurrence of 100-year flood in 1993 mentioned. Not all of this population are going to be experiencing this at the same time. There was a flood this year (2020), high enough discharge that spawning substrate were mobilized, and likely impact spawning habitat. Visual surveys identified redds, which were subsequently buried. This year there were a number of significant rainfall events that have barred migration of some fish past Big Bar. When the rain events subsided passage resumed.

Classification of Threats adopted from IUCN-CMP, Salafsky et al. (2008)

B.8. THREATS CALCULATOR RESULTS FOR DU21 TAKLA-TREMBLEUR S

Table B.13. Overall Threat Impact DU21 Takla-Trembleur S

Threat Impact		Level 1 Threat Impact Counts: high range	Level 1 Threat Impact Counts: low range
A	Very High	0	0
B	High	2	1
C	Medium	5	3
D	Low	1	4
Calculated Overall Threat Impact:		Very High	Very High

Assigned Overall Threat Impact: **B = High**

Impact Adjustment Reasons: High abundance suggests this DU is not facing imminent extirpation (i.e. 3 generations)

Overall Threat Comments This DU was assigned a ranking of B = High, which was adjusted down from A = Very High. There are many significant threats facing this DU, but the group did not feel this stock was in danger of going extinct in the next 3 generations. This DU is less threatened from Big Bar when compared to Early Stuart or other earlier timed runs, yet the Big Bar landslide still poses a significant threat. The primary threats facing this DU are climate change, landslides (Big Bar), ecosystems modifications, and fishing.

Table B.14. Threats Calculator Table DU21 Takla-Trembleur S

No.	**Threat**	**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
		Range	**Description**				
1	Residential & commercial development	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	-
1.1	Housing & urban areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	All Sockeye from this DU pass through the lower Fraser River (pervasive scope), but they transit the area rapidly and are unlikely to be greatly impacted by the footprint of new residential/urban developments. The footprint from these developments above the lower Fraser likely insignificant at the DU level. The group felt there likely are impacts but their severity is currently unknown.
1.2	Commercial & industrial areas	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	All Sockeye from this DU pass through the lower Fraser River (pervasive scope), but they transit the area rapidly and are therefore unlikely to be greatly impacted by new industrial or commercial developments. The lower Fraser River is highly developed and the remaining habitat is currently more prone to industrial development than housing. The footprint from these developments were thought to have a negligible impact at the population level.
1.3	Tourism & recreation areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	All Sockeye from this DU pass through the lower Fraser where there is the highest concentration of tourism developments (boat launches, marinas, etc.; pervasive scope), yet the impacts are unknown. As with the other development categories these fish transit the lower Fraser rapidly and are not anticipated to be greatly impacted by the footprint of tourism development.
2	Agriculture & aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	-
2.1	Annual & perennial non-timber crops	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Annual and perennial non-timber crops are not anticipated to be major threat for this DU, as most of these activities occur in the lower Fraser where fish rapidly migrate through. A restricted portion of the population (11-30%) is expected to encounter these developments during outmigration or their return spawning migration, but likely has a slight impact at the DU level.
2.2	Wood & pulp plantations	-	-	-	-	-	Not anticipated to be a threat - no footprints of wood/pulp plantations in Sockeye salmon habitat.
2.3	Livestock farming & ranching	-	Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	There is little in the way of cattle ranching in the Stuart drainage, and the streams are generally too deep for cattle to transit. It is therefore unlikely there will be in-river impacts from cattle trampling or habitat degradation from cattle. DU21 will be less susceptible to cattle impacts than the Early Stuart DU as the larger lake-headed streams and lake spawning areas are too deep.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
2.4	Marine & freshwater aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	**Fish Farms:** The physical footprint of aquaculture net-pens is not anticipated to be a threat to this DU. Other effects such as disease transmission is scored elsewhere. **Hatchery Competition:** Sockeye from this DU will experience competition with other salmon in the Pacific ocean (≈40% hatchery origin), including hatchery fish from BC, the U.S., Russia, and Japan. There are large salmon farming operations in the North Pacific that likely impact fish from this DU, but the impacts aren't well understood. The group cited a paper by Connors and a decrease in productivity, the following is taken from this paper: Connors et al (2020) reports from 2005 to 2015, the approximately 82 million adult Pink Salmon produced annually from hatcheries were estimated to have reduced the productivity of southern Sockeye Salmon by ~15%, on average. Additionally, Ruggerone and Connors (2015) report Pink Salmon abundance in the second year of Sockeye life at sea is a key factor contributing to the decline of Sockeye Salmon productivity. An increase from 200 to 400 million Pink Salmon in the North Pacific is predicted to reduce Fraser Sockeye recruitment by 39%. Length-at-age of Fraser Sockeye Salmon also declined with greater Sockeye and Pink Salmon abundance, and age at maturity increased with greater Pink Salmon abundance. Group also mentioned juvenile Sockeye en route to southern Alaska have diet/habitat overlap with Chum Salmon along the coast of BC.
3	Energy production & mining	-	-	-	-	-	-
3.1	Oil & gas drilling	-	-	-	-	-	Not anticipated to be a threat - no oil and gas drilling anticipated to occur within Sockeye Salmon habitat.
3.2	Mining & quarrying	-	-	-	-	-	Not anticipated to be a threat - gravel extraction likely not an issue as these fish transit the lower Fraser River quickly, and do not rely on this habitat enough to be impacted. Group was unsure of significant placer mining in the Stuart drainage, although Pinchi Mine mentioned as a potential source. Direct impacts from these activities are likely to be neglible (pollution and other associated impacts scored elsewhere).
3.3	Renewable energy	-	-	-	-	-	Not anticipated to be a threat - footprint from solar, tidal, wind energy not anticipated to encroach on Fraser Sockeye habitat.
4	Transportation & service corridors	-	Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	-
4.1	Roads & railroads	-	Unknown	Small (1-10%)	Unknown	High (Continuing)	Not many roads in this area, with proper mitigation impacts from new road development will likely be minimal. Overall a small portion of population subject to road development, severity unknown. There is more road access here than DU20 and the Pacific Salmon Explorer shows a marked difference (more) in road development when compared to Early Stuart. Spawning occurs in larger or lake-headed rivers, and are likely more buffered than Early Stuart streams from road/railroad effects. Potential impacts from railway crossings with respects to Sockeye passage (does not include pollution and other associated effects).
4.2	Utility & service lines	-	Negligible	Small (1-10%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Transmountain pipline expansion in lower Fraser was raised, group felt that even if a small portion of the population was exposed to expansion activities the effects would likely be neglible.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
4.3	Shipping lanes	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Dredging activities and log storage in the in the lower Fraser River are not anticipated to impact this DU, as they rapidly migrate through the area, timing of dredging activities is misaligned.
4.4	Flight paths	-	-	-	-	-	Not anticipated to be a threat
5	Biological resource use	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	-
5.1	Hunting & collecting terrestrial animals	-	-	-	-	-	Not anticipated to be a threat
5.2	Gathering terrestrial plants	-	-	-	-	-	Not anticipated to be a threat
5.3	Logging & wood harvesting	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	There is no salvage logging in this area from fires or pest infestations, no in-river logging to the groups knowledge. Future liklihood of fire in the drainage is high, and there could be impacts within the next 3 generations. DU21 is less likely to be impacted by fire than the Early Stuart DU, however the group felt given the high fire risk there may be slight effects on a restricted (11-30%) proportion of the DU.
5.4	Fishing & harvesting aquatic resources	BC	High - Medium	Pervasive (71-100%)	Serious – Moderate (11-70%)	High (Continuing)	Exploitation rate on this DU is highly affected by TAC that is set at the management unit level and mixed stock fisheries. ER on this DU will typically be affected by fisheries directed on Summer Run (usually driven by Chilko abundance), Late Run (usually driven by Late Shuswap abundance), and Fraser Pink Salmon. Estimated ERs for 2018 & 2019 are <10% (subject to similar concerns re: estimation error as noted in Early Stuart), but are on the lower range of ERs in recent years (7-55%). If we stay within exploitation rates the populations shouldn't decline. In years of high abundance populations can likely sustain higher exploitation rates, but we need to recognize that we likely exceed targets. Incidental mortality from Chinook fisheries mentioned. Mixed stock fisheries effects when managing MUs (run timing groups) as weaker stocks are co-harvested, and this is an international issue. The group agreed that 11-70% was appropriate for severity (high range of uncertainty) with the acknowledgement that this is under current management. If management regimes are more conservative in the future on non-dominant years, the severity could be on the lower end of uncertainty. Fishing may change in the next 10 years due to repeated low escapements. Harvest regime may change in coming years. Comments within the group that basing severity of last 2 years is problematic, although longer term (20 years back) is also problematic due to the high variability in abundance/productivity.
6	Human intrusions & disturbance	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	-
6.1	Recreational activities	D	Low	Small(1-10%)	Slight (1-10%)	High (Continuing)	There is more access to areas of DU21 than the Early Stuart DU, and a potential higher probability of increased recrational activities; however, most of these streams are larger than Estu spawning streams and deeper, therefore ATV/UTV traffic or foot traffic unlikely. Also potential impacts from jet boats.
6.2	War, civil unrest & military exercises	-	-	-	-	-	Not anticipated to be a threat

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
6.3	Work & other activities	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Handling stress at Big Bar and Whoosh system during upstream migration, although Whoosh has been decommissioned. Fishway at Big Bar may have continued impacts, as tagging and brood collection will continue. Most activities are in the best interest of fish, but tagging stress still occurs as we are tagging fish to investigate passage. If fish are transported by truck there will be some mortality. Test fishing impacts when releasing fish (some disagreement) - still within 1-10% range . Activities at Big Bar will likely impact a low proportion of these fish (i.e. if you tag several hundred fish at Big Bar a very small proportion will be Late Stuarts), as they have a better chance of natural passage compared to Early Stuarts. One out of four years there will be a mark recapture on Tachie river, so there is additional stress during these activities. mark-recapture programs are not anticipated to have significant impacts on Sockeye, fish have already reached spawning areas and don't have far to go. Tagging programs for Chum and Chinook can also intercept Sockeye.
7	Natural system modifications	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	-
7.1	Fire & fire suppression	D	Low	Small (1-10%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	There have been several major fires in the Stuart watershed, but the majority has been unaffected by fire. There are currently no fires in the drainage but we expect some of it to burn in future years, and within the next 3 generations (moderate timing). If there is a large fire there would be an impact on thermal regimes of the streams in this DU, but the Stuart is a large watershed, and a fire will likely affect a small portion of the overall DU area. DU21 will likely be less affected by the direct effects of fires than DU20 due to the fact they spawn in more stable lake-headed streams, and in deeper water buffering them from thermal impacts in the event of a fire (sedimentation/pollution/changes in runoff dynamics scored elsewhere).
7.2	Dams & water management/use	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Significant transference of Nechako water by Kemano Dam releases - 70% less water in the system, when air temp warmer water heats up quickly and contribute to high temps. Reduced ability of water to absorb heat without increasing water temperatures. Early Stuart and Late stuarts are differently exposed, potentially more of an issue later in the summer. Early timing of DU20 sometimes miss this. If Kemano dam was not there, there would be considerably more warm cold released and would be less fluctuations. Mitigation efforts to reduce the effects from Kemano Dam were questioned, as increasing air temperatures reduce our ability to mitigate temperature effects. In years when biological limits are being stretched during migration, the additional ATU from the warmer water they encounter can contribute substantially to pre-spawn mortality and other migration effects.
7.3	Other ecosystem modifications	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	Forestry, wildfires, agriculture and development are known to impact stream temperature and flow regimes due to increases in impervious surfaces. Sockeye from the late Stuart DU spawn in larger lake-headed streams which are more buffered from thermal effects and discharge levels.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
8	Invasive & other problematic species & genes	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	-
8.1	Invasive non-native/alien species	-	-	-	-	-	Not anticipated to be a threat
8.2	Problematic native species	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	Similar impacts to DU20 expected
8.3	Introduced genetic material		Unknown	Unknown	Unknown	High - Low	Unknown impacts from Big Bar enhancement efforts, activities could potentially occur in the near future, and long term.
9	Pollution	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	-
9.1	Household sewage & urban waste water	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	Fraser Sockeye are exposed to contaminants from many sources in freshwater, the Fraser estuary, and Strait of Georgia. These include PCBs, PCDs, metals, household pharmaceuticals, personal care products, pesticides, etc., particularly in the lower Fraser and estuary. We don't generally see direct mortality but pollution can lead to decreased productivity and fewer offspring through a variety of mechanisms. The group drew off previous work from the Fraser Chinook RPA, which indicated the threat is pervasive (71-100% exposed) and could potentially lead to declines ranging from 1-30%. The group agreed Chinook are more prone to the effects from pollution due to their life history, and the impacts on Sockeye would likely be less. There is considerable uncertainty surrounding the severity and there is less literature to draw off compared to Chinook, but the group agreed that the impacts could potentially be higher than 10%, but unlikely to be as high as a 30% population level decline. **This score was also given to subsequent categories 9.2 Industrial & military effluents, 9.3 Agricultural & forestry effluents, and 9.5 Air-borne pollution.**
9.2	Industrial & military effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.3	Agricultural & forestry effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.4	Garbage & solid waste	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	This includes micro plastics, abandoned fishing gear. The group felt that all Sockeye are exposed to microplastics, and some may encounter abandoned nets, however, there is currently insufficient information to determine severity.
9.5	Air-borne pollutants	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.6	Excess energy	-	Unknown	Unknown	Unknown	Unknown	Noise and excess light are considered here, although the scope/severity/timing is unknown.
10	Geological events	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	-
10.1	Volcanoes	-	-	-	-	-	Not anticipated to be a threat
10.2	Earthquakes/ tsunamis	-	-	-	-	-	Not anticipated to be a threat
10.3	Avalanches/ landslides	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	The group felt the impacts from Big Bar are considerably less than for the Early Stuart, but still posed a moderate threat (11-30%).

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
11	Climate change & severe weather	B	High	Pervasive (71-100%)	Serious (31-70%)	High (Continuing)	-
11.1	Habitat shifting & alteration	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	**Marine habitat:** This includes sea level rise, ocean acidification, marine heatwaves/temperatures. Directed work by Jackie King highlighted. There has been another blob (heatwave), we've now seen the highest water temperatures in the Gulf of Alaska (GOA) in the last 50 years. This suggests these large changes are going to continue yet there is considerable uncertainty as to what the impact will be. Effects on growth in early marine period has an impact on survival of first winter. GOA surveys looking at fish condition after marine winter, however there are currently no results. We do know catches were not what we expected for age classes and we've seen poor returns. There have been better than expected returns for several stocks, and it was mentioned maybe marine survival problems have less effect. There was some question as to how different enumeration methods would lead to different results. **Freshwater habitat:** This DU is likely to be less affected by freshwater habitat shifting/alteration compared to EStu, however the group felt that given the uncertainty in the marine environment, paired with increasing frequency of discharge/temperature events, the severity of serious-moderate (11-70%) was appropriate, with the acknowledgement this is unlikely at the high end of the range (70%).
11.2	Droughts	-	Negligible	Large (31-70%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Fish from this DU spawn in larger streams that are buffered from drought effects, and drought effects in the mainstem Fraser are not expected to be a threat. If a drought occurs on a large return year the group agreed the scope could be between 31-70%, but the severity would be negligible for those fish if exposed.
11.3	Temperature extremes	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	Late stuart anticipated to have less severe impacts than EStu population due to their later migration timing and the buffering effects of the larger spawning streams and lake-headed systems. Temperature extremes could affect the same proportion of population in the event of a dominant year return (31-70% scope). The group agreed 11-30% severity was appropriate.
11.4	Storms & flooding	D	Low	Restricted – Small (1-30%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Floods less likely to impact late Stuart population due to the larger sized spawning streams and their buffering effects. Group agreed there could still be a small portion of the population exposed to flood effects (small-restricted 1-30% chosen due to uncertainty in proportion exposed). Significant floods do not occur regularly, but are expected to occur within the next 3 generations.

Classification of Threats adopted from IUCN-CMP, Salafsky et al. (2008)

B.9. THREATS CALCULATOR RESULTS FOR DU22 TASEKO-ES

Table B.15. Overall Threat Impact DU22 Taseko-ES

		Level 1 Threat Impact Counts	
Threat Impact		high range	low range
A	Very High	0	0
B	High	4	0
C	Medium	3	4
D	Low	1	4
Calculated Overall Threat Impact:		Very High	Very High

Assigned Overall Threat Impact: **AB = Very High - High**

Impact Adjustment Reasons: No Adjustment

Overall Threat Comments This DU was assigned a ranking of AB = Very High - High. This DU is small and has very low abundance, and it was agreed upon there is the potential for extinction in the next 3 generations, particularly in light of the Big Bar landslide. The threats to this DU come primarily from climate change, landslides (Big Bar), ecosystems modifications, and fishing.

Table B.16. Threats Calculator Table DU22 Taseko-ES

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
1	Residential & commercial development	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	-
1.1	Housing & urban areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	All Sockeye from this DU pass through the lower Fraser River (pervasive scope), but they transit the area rapidly and are unlikely to be greatly impacted by the footprint of new residential/urban developments. The footprint from these developments above the lower Fraser likely insignificant at the DU level. The group felt there likely are impacts but their severity is currently unknown.
1.2	Commercial & industrial areas	-	-	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	All Sockeye from this DU pass through the lower Fraser River (pervasive scope), but they transit the area rapidly and are therefore unlikely to be greatly impacted by new industrial or commercial developments. The lower Fraser River is highly developed and the remaining habitat is currently more prone to industrial development than housing The footprint from these developments were thought to have a negligible impact at the population level.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
1.3	Tourism & recreation areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	All Sockeye from this DU pass through the lower Fraser where there is the highest concentration of tourism developments (boat launches, marinas, etc.; pervasive scope), yet the impacts are unknown. As with the other development categories these fish transit the lower Fraser rapidly and are not anticipated to be greatly impacted by the footprint of tourism development.
2	Agriculture & aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	-
2.1	Annual & perennial non-timber crops	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Annual and perennial non-timber crops are not anticipated to be major threat for this DU, as most of these activities occur in the lower Fraser where fish rapidly migrate through. A restricted portion of the population (11-30%) is expected to encounter these developments during outmigration or their return spawning migration, but likely has a slight impact at the DU level.
2.2	Wood & pulp plantations	-	-	-	-	-	Not anticipated to be a threat
2.3	Livestock farming & ranching	-	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	There could be impacts within the migratory route of this DU, but the group felt there would be neglible impacts at the DU level.
2.4	Marine & freshwater aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	**Fish Farms:** The physical footprint of aquaculture net-pens is not anticipated to pose a threat to FRS. Other effects such as disease transmission is scored elsewhere. **Hatchery Competition:** Sockeye from this DU will experience competition with other salmon in the Pacific ocean (≈40% hatchery origin), including hatchery fish from BC, the U.S., Russia, and Japan. There are large salmon farming operations in the North Pacific that likely impact fish from this DU, but the impacts aren't well understood. The group cited a paper by Connors and a decrease in productivity, the following is taken from this paper: Connors et al (2020) reports from 2005 to 2015, the approximately 82 million adult Pink Salmon produced annually from hatcheries were estimated to have reduced the productivity of southern Sockeye Salmon by ~15%, on average. Additionally, Ruggerone and Connors (2015) report Pink Salmon abundance in the second year of Sockeye life at sea is a key factor contributing to the decline of Sockeye Salmon productivity. An increase from 200 to 400 million Pink Salmon in the North Pacific is predicted to reduce Fraser Sockeye recruitment by 39%. Length-at-age of Fraser Sockeye Salmon also declined with greater Sockeye and Pink Salmon abundance, and age at maturity increased with greater Pink Salmon abundance. Group also mentioned juvenile Sockeye en route to southern Alaska have diet/habitat overlap with Chum Salmon along the coast of BC.
3	Energy production & mining	-	-	-	-	-	-
3.1	Oil & gas drilling	-	-	-	-	-	Not anticipated to be a threat
3.2	Mining & quarrying	-	-	-	-	-	There is mining activity within the Taseko area (3 mining tenures on Salmon Explorer). Mine within area in caretaker mode currently and can start up at any time. First Nations have fought against development in region, future development unlikely to expand into habitat. Fish Lake example mentioned.
3.3	Renewable energy	-	-	-	-	-	Not anticipated to be a threat

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
4	Transportation & service corridors	-	Negligible	Negligible(<1%)	Unknown	High (Continuing)	-
4.1	Roads & railroads	-	Negligible	Negligible (<1%)	Unknown	High (Continuing)	Road density very low in this DU, the group anticipated a negligible portion of the DU will encounter these developments/activities but the impacts are unknown.
4.2	Utility & service lines	-	Negligible	Small (1-10%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Limited to expansion of Transmountain Pipeline in lower Fraser, all fish must migrate past but unknown severity.
4.3	Shipping lanes	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	The lower Fraser is a highly active shipping lane, and dredging activities occur in this area. All fish are likely exposed to these activities (pervasive scope) but the impacts are unknown.
4.4	Flight paths	-	-	-	-	-	N/A
5	Biological resource use	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	-
5.1	Hunting & collecting terrestrial animals	-	-	-	-	-	Not anticipated to be a threat
5.2	Gathering terrestrial plants	-	-	-	-	-	Not anticipated to be a threat
5.3	Logging & wood harvesting	-	-	-	-	-	No large fires or pest infestations have occurred within the spawning area of this DU, and while portions of their migratory route has been impacted the in-river impacts from salvage logging operations are not anticipated to be a threat.
5.4	Fishing & harvesting aquatic resources	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	Small stock that co-migrates with other Early Summer and some Summer stocks. Difference is we have less info about timing, more difficult to try and build windows in harvest plan to protect these fish. Do assessment of spawning grounds but no defensible/reliable estimates, small sample size. This group would be aggregated with others. Stock ID - confusion between Taseko and Chilko. Timing seems to be a bit later than other Early Summers. Does not have benefit of fishing protection as does Bowron - extension of window closure does not protect well due to later and fluctuating timing. In a lot of years we're not targeting early summers, moderate severity (11-70%) was felt to be appropriate. The impact is likely not at the high range of this (70%), although exploitation rates of 50% were discussed. On dominant Shuswap years the ER will likely be high, but on non-dominant years the ER will likely be less than 30%.
6	Human intrusions & disturbance	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	-
6.1	Recreational activities	-	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Most of spawning in lake, limited stream habitat very remote. Hunting activities in area, could be potential negligible impacts.
6.2	War, civil unrest & military exercises	-	-	-	-	-	Not anticipated to be a threat

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
6.3	Work & other activities	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Group feels restricted portion exposed with potentially slight impacts - Big Bar tagging is expected to continue for several years, although overtime there will likely be less interactions with research activities, group felt restricted was a more appropriate scope.
7	Natural system modifications	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	-
7.1	Fire & fire suppression	D	Low	Small (1-10%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	There have been recent and severe fires in area. More are expected in the next 3 generations, and this area is more likely prone to fires than Bowron/Quesnel/Stuart system. High-moderate agreed upon for timing. Actual areas where fish spawn, both in stream (not in vegetated areas that will burn easily) and in lake not likely.
7.2	Dams & water management/use	-	-	-	-	-	Likely a good parallel with the Bowron - no dams impacting this DUs, just exposure to flood control structures in lower Fraser. Minimal, if any, water extraction.
7.3	Other ecosystem modifications	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	Taseko is a relatively intact watershed, migration impacts from Chilcotin and mainstem Fraser (same rationale as other DUs).
8	Invasive & other problematic species & genes	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	-
8.1	Invasive non-native/alien species	-	-	-	-	-	Not anticipated to be a threat
8.2	Problematic native species	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	At lower abundances Sockeye populations can be significantly impacted by predation (Carl Walters quoted) - pinniped predation. If predator populations are going up there will likely be a concurrent increase in predation, however for pinnipeds, populations appear to be stable. Other marine (White-sided Dolphins) and terrestrial mammals (bears), avian predators (cormorants, mergansers, herons, eagles) were discussed, but question about them being out of balance due to human activities. Study quoted indicating higher predation on Sockeye with disease indicating fish being preyed on are in poor condition. Group felt that due to the low abundance this DU could have more than a slight impact, but due to the uncertainty with salmon/predator dynamics there could be potentially higher impacts. The group acknowledges this is not likely at the high end of the range (30%), but could potentially be higher than 10%.
8.3	Introduced genetic material	-	Unknown	Unknown	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	This year there was an attempt to collect Brood stock from Taseko as part of emergency conservation enhancement. Was not successful. Going forward there will be continued effort to do this, although there are inherent challenges in collecting brood from this system. If there was enhancement there could be introductions of genetic material, risk of introducing Chilko fish to Taseko unintentionally.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
9	Pollution	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	-
9.1	Household sewage & urban waste water	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight(1-30%)	High (Continuing)	Fraser Sockeye are exposed to contaminants from many sources in freshwater, the Fraser estuary, and Strait of Georgia. These include PCBs, PCDs, metals, household pharmaceuticals, personal care products, pesticides, etc., particularly in the lower Fraser and estuary. We don't generally see direct mortality but pollution can lead to decreased productivity and fewer offspring through a variety of mechanisms. The group drew off previous work from the Fraser Chinook RPA, which indicated the threat is pervasive (71-100% exposed) and could potentially lead to declines ranging from 1-30%. The group agreed Chinook are more prone to the effects from pollution due to their life history, and the impacts on Sockeye would likely be less. There is considerable uncertainty surrounding the severity and there is less literature to draw off compared to Chinook, but the group agreed that the impacts could potentially be higher than 10%, but unlikely to be as high as a 30% population level decline. **This score was also given to subsequent categories 9.2 Industrial & military effluents, 9.3 Agricultural & forestry effluents, and 9.5 Air-borne pollution.**
9.2	Industrial & military effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	Placer mine in area, group did not feel it was appropriate to change score - see 9.1 Household sewage & urban waste.
9.3	Agricultural & forestry effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.4	Garbage & solid waste	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	This includes micro plastics, abandoned fishing gear. The group felt that all Sockeye are exposed to microplastics, and some may encounter abandoned nets, however, there is currently insufficient information to determine severity.
9.5	Air-borne pollutants	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.6	Excess energy	-	Unknown	Unknown	Unknown	Unknown	Noise and excess light are considered here, although the scope/severity/timing is unknown.
10	Geological events	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	-
10.1	Volcanoes	-	-	-	-	-	Not anticipated to be a threat
10.2	Earthquakes/ tsunamis	-	-	-	-	-	Not anticipated to be a threat
10.3	Avalanches/ landslides	BC	High - Medium	Pervasive (71-100%)	Serious – Moderate (11-70%)	High (Continuing)	Similar effects to Big Bar compared to Bowron - lots of uncertainty around timing, could differ from Bowron within ES group. 2004 there was slide in Chilcotin in Farwell Canyon. Unlike the other systems we've assessed there have been slides in the Chilcotin watershed - especially lower Chilcotin. Unstableness of watershed due to burns, rainfall events can interact with unstable geomorphology of lower canyon. There are massive sediment inputs from rain on burned land events.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Description				
11	Climate change & severe weather	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	-
11.1	Habitat shifting & alteration	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	**Marine habitat:** This includes sea level rise, ocean acidification, marine heatwaves/temperatures. Directed work by Jackie King highlighted. There has been another blob (marine heatwave), we've now seen the highest water temperatures in the Gulf of Alaska (GOA) in the last 50 years. This suggests these large changes are going to continue yet there is considerable uncertainty as to what the impact will be. Effects on growth in early marine period has an impact on survival of first winter. GOA surveys looking at fish condition after marine winter, however there are currently no results. We do know catches were not what we expected for age classes and we've seen poor returns. There have been better than expected returns for several stocks, and it was mentioned maybe marine survival problems have less effect. There was some question as to how different enumeration methods would lead to different results. **Freshwater habitat:** Earlier onset of freshet, high flows, temperature effects. High discharge events are occurring more frequently as well as increases in long term temperature averages. **Score:** The group felt that all fish are exposed (pervasive 71-100%) but an uncertainty range of serious-moderate (11-70%) for severity was deemed appropriate. There was discussion of how some years will be worse than others, and there is the potential for this threat to exceed a 70% population level decline but is expected to be unlikely.
11.2	Droughts	-	-	-	-	-	Not anticipated to be a threat - Taseko is a glacial system, droughts are highly unlikely.
11.3	Temperature extremes	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	Temperature extremes buffered from large streams and lakes, impacts just from mainstem Fraser River. Similar impacts to Bowron, due to timing will experience high temperatures during migration.
11.4	Storms & flooding	D	Low	Restricted – Small (1-30%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Substantial flooding in Big Creek and Chilcotin, some evidence of migration barriers at really high flows. Mostly lake spawning, likely not much of an impact. Historically there is little in the way of flooding of spawning tributaries. Mainstem Fraser impacts.

Classification of Threats adopted from IUCN-CMP, Salafsky et al. (2008)

B.10. THREATS CALCULATOR RESULTS FOR DU24 WIDGEON-RT

Table B.17. Overall Threat Impact DU22 Taseko-ES

Threat Impact		Level 1 Threat Impact Counts: high range	Level 1 Threat Impact Counts: low range
A	Very High	0	0
B	High	2	0
C	Medium	4	2
D	Low	0	4
Calculated Overall Threat Impact:		Very High	High

Assigned Overall Threat Impact: **B = High**

Impact Adjustment Reasons: Adjusted down; recent population trend does not suggest 100% reduction is realistic

Overall Threat Comments We assigned an overall impact rating of B = High. This score was adjusted down from AB = Very High – High, as recent population trends do not suggest a 100% population level reduction is realistic in the next 3 generations. The threat rating was primarily based on climate change, pollution, fishing, hatchery competition, and predation. It should be noted this is a single spawning site DU and could be significantly impacted by a major event.

Table B.18. Threats Calculator Table DU22 Taseko-ES

No.	Threat	Impact (calculated) Range	Impact (calculated) Distribution	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	-
1.1	Housing & urban areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Could potentially be more impacts than other lake-type DUs - these fish reside in lower Fraser for a longer period of time, so the likelihood of these fish encountering and being impacted by new developments may be increased. The group felt this is still unknown severity.
1.2	Commercial & industrial areas	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	See above comment (1.1 Housing & Urban Developmnent), although group still feels this is likely a negligible impact at the DU level.
1.3	Tourism & recreation areas	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Plans for tourism development in DU area, could be potential impacts if development occurs. Still unknown.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Distribution				
2	Agriculture & aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	-
2.1	Annual & perennial non-timber crops	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	These fish spawn in the lower reaches of the Fraser and spend more time than other DUs in the lower Fraser on their outmigration to the SOG. These fish could potentially encounter agricultural development but the group feels these impacts would be slight (1-10%).
2.2	Wood & pulp plantations	-	-	-	-	-	Not anticipated to be a threat
2.3	Livestock farming & ranching	-	-	-	-	-	Not anticipated to be a threat
2.4	Marine & freshwater aquaculture	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	Potentially not the same weight as other DUs as a larger proportion of juveniles migrate through Juan de Fuca Strait, although group felt given the uncertainty the range was still appropriate.
3	Energy production & mining	-	-	-	-	-	-
3.1	Oil & gas drilling	-	-	-	-	-	Not anticipated to be a threat
3.2	Mining & quarrying	-	-	-	-	-	Not anticipated to be a threat
3.3	Renewable energy	-	-	-	-	-	Not anticipated to be a threat
4	Transportation & service corridors	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	-
4.1	Roads & railroads	-	Unknown	Restricted (11-30%)	Unknown	High (Continuing)	There are roads in surrounding area
4.2	Utility & service lines	-	Negligible	Small (1-10%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Limited to expansion of Transmountain Pipeline in lower Fraser - these fish may be exposed to these activities in the near future (moderate timing), but the group felt a small portion of the population would likely be exposed. Given proper mitigations this is likely a negligible threat.
4.3	Shipping lanes	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	The lower Fraser is a highly active shipping lane, and dredging activities occur in this area. All fish are likely exposed to these activities (pervasive scope) but the impacts are unknown. **Unique to this DU:** there is also log booming along the Pitt, score not altered but could potentially lead to additional impacts.
4.4	Flight paths	-	-	-	-	-	N/A
5	Biological resource use	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	-
5.1	Hunting & collecting terrestrial animals	-	-	-	-	-	Not anticipated to be a threat
5.2	Gathering terrestrial plants	-	-	-	-	-	Not anticipated to be a threat
5.3	Logging & wood harvesting	-	-	-	-	-	Not anticipated to be a threat
5.4	Fishing & harvesting aquatic resources	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	No ERs, just a proxy. Summer Run MU was used as a proxy. Should have similar fishing impacts to late Stuart due to timing.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Distribution				
6	Human intrusions & disturbance	-	Unknown	Restricted (11-30%)	Unknown	High (Continuing)	-
6.1	Recreational activities	-	Unknown	Restricted (11-30%)	Unknown	High (Continuing)	Lower section of Pitt River a high traffic area. Widgeon fish spawning at high tide in Widgeon Slough. Reports of jet boats entering Widgeon Slough. Stranding, sucking up fish in impellers, although unknown impacts - no evidence. Most impacts for boats during summer. Lots of jet boat impact in Upper Pitt but likely not affecting Widgeon fish. Sockeye are spawning there during a period where there is less activitiy, but not well known. Jet boat ban is Transport Canada decision, province would have to file request.
6.2	War, civil unrest & military exercises	-	-	-	-	-	Not anticipated to be a threat
6.3	Work & other activities	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Foot surveys throughout spawning period, negligible impacts
7	Natural system modifications	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	-
7.1	Fire & fire suppression	-	-	-	-	-	Not anticipated to be a threat
7.2	Dams & water management/use	-	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Flood control structures impact rearing fish from this DU, likely negligible impacts.
7.3	Other ecosystem modifications	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	Sockeye from this DU have the shortest freshwater migration distance and are least likely to be impacted by the ecosystem modifications other DUs experience. Mainstem hydrology issues from upper Pitt River modifications - most changes aleady occurred. Given the uncertainty 1-30% severity was deemed appropriate, but likely not on the high end of the range (30%).
8	Invasive & other problematic species & genes	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	-
8.1	Invasive non-native/alien species	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	There are a number of invasive species in the lower Fraser, and fish from this DU are most likely to encounter them as river-type.
8.2	Problematic native species	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	At lower abundances Sockeye populations can be significantly impacted by predation (Carl Walters quoted) - pinniped predation. If predator populations are going up there will likely be a concurrent increase in predation, however for pinnipeds, populations appear to be stable. Other marine (White-sided Dolphins) and terrestrial mammals (bears), avian predators (cormorants, mergansers, herons, eagles) were discussed, but question about them being out of balance due to human activities. Study quoted indicating higher predation on Sockeye with disease indicating fish being preyed on are in poor condition. Group felt that due to the low abundance this DU could have more than a slight impact, but due to the uncertainty with salmon/predator dynamics there could be potentially higher impacts. The group acknowledges this is not likely at the high end of the range (30%), but could potentially be higher than 10%.
8.3	Introduced genetic material	-	-	-	-	-	Not anticipated to be a threat

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Distribution				
9	Pollution	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	-
9.1	Household sewage & urban waste water	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	Fraser Sockeye are exposed to contaminants from many sources in freshwater, the Fraser estuary, and Strait of Georgia. These include PCBs, PCDs, metals, household pharmaceuticals, personal care products, pesticides, etc., particularly in the lower Fraser and estuary. We don't generally see direct mortality but pollution can lead to decreased productivity and fewer offspring through a variety of mechanisms. The group drew off previous work from the Fraser Chinook RPA, which indicated the threat is pervasive (71-100% exposed) and could potentially lead to declines ranging from 1-30%. The group agreed Chinook are more prone to the effects from pollution due to their life history, and the impacts on Sockeye would likely be less. There is considerable uncertainty surrounding the severity and there is less literature to draw off compared to Chinook, but the group agreed that the impacts could potentially be higher than 10%, but unlikely to be as high as a 30% population level decline. **This score was also given to subsequent categories 9.2 Industrial & military effluents, 9.3 Agricultural & forestry effluents, and 9.5 Air-borne pollution.**
9.2	Industrial & military effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.3	Agricultural & forestry effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.4	Garbage & solid waste	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	This includes micro plastics, abandoned fishing gear. The group felt that all Sockeye are exposed to microplastics, and some may encounter abandoned nets, however, there is currently insufficient information to determine severity.
9.5	Air-borne pollutants	CD	Medium - Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	See 9.1 Household sewage & urban waste
9.6	Excess energy	-	Unknown	Unknown	Unknown	Unknown	Noise and excess light are considered here, although the scope/severity/timing is unknown.
10	Geological events	-	-	-	-	-	-
10.1	Volcanoes	-	-	-	-	-	Not anticipated to be a threat
10.2	Earthquakes/tsunamis	-	-	-	-	-	Not anticipated to be a threat
10.3	Avalanches/landslides	-	-	-	-	-	Not anticipated to be a threat
11	Climate change & severe weather	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	-
11.1	Habitat shifting & alteration	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	**Marine habitat:** This includes sea level rise, ocean acidification, marine heatwaves/temperatures. Directed work by Jackie King highlighted. There has been another blob (marine heatwave), we've now seen the highest water temperatures in the Gulf of Alaska (GOA)in the last 50 years. This suggests these large changes are going to continue yet there is considerable uncertainty as to what the impact will be. Effects on growth in early marine period have an impact on survival of first winter.

No.	Threat	Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
		Range	Distribution				
							GOA surveys looking at fish condition after marine winter, however there are currently no results. We do know catches were not what we expected for age classes and we've seen poor returns. There have been better than expected returns for several stocks, and it was mentioned maybe marine survival problems have less effect. There was some question as to how different enumeration methods would lead to different results. **Freshwater habitat:** This DU is likely to be the least threatened by freshwater habitat shifts, as they have the shortest upstream migration of all DUs. These fish are, however, more prone to shifts in habitat in the lower Fraser due to their extended residence time compared to lake-type Sockeye. **Score:** The group felt that all fish are exposed (pervasive 71-100%) but an uncertainty range of serious-moderate (11-70%) for severity was deemed appropriate. There was discussion of how some years will be worse than others, and there is the potential for this threat to exceed a 70% population level decline but is expected to be unlikely. Same score as lake-type Sockeye retained.
11.2	Droughts	-	-	-	-	-	Drought not anticipated to impact Widgeon
11.3	Temperature extremes	CD	Medium - Low	Large - Restricted (11-70%)	Moderate (11-30%)	High (Continuing)	We think these fish come into lower Fraser in August, could potentially experience high temperatures. Very few samples for Widgeon confounding migration timing, but group feels this DU will experience temperature extremes. Likely same impacts as Taseko and Late Stuart. Mainstem Fraser gets warm and can impact this DU.
11.4	Storms & flooding	-	-	-	-	-	Likely not a major impact for Widgeon, tidal influence

Classification of Threats adopted from IUCN-CMP, Salafsky et al. (2008)

APPENDIX C. SOURCES OF UNCERTAINTY AND RESEARCH NEEDS

The following sections list research needs and sources of uncertainty identified throughout the RPA. This list should not be considered exhaustive, and some of the items identified are currently being investigated.

C.1. FRESHWATER HABITAT

- Research is needed to better understand fine-detailed spawning habitat use for FRS. Spawning reaches have been identified within FRS habitat but there is currently limited information surrounding factors such as the annual quality or quantity of appropriate spawning substrates.
- There is limited information on rearing habitat within FRS nursery lakes, other than general estimates of pelagic zone areas and infrequent sampling for water quality and plankton density/composition. More detailed research surrounding nursery lake productivity and environmental conditions is needed to better understand and protect FRS rearing habitat, and to potentially improve smolt condition (i.e. larger smolts have better ocean survival in early marine period).
- We currently have a limited understanding of habitat use and behaviour for DU24 (Widgeon-RT), and much of our understanding come from observations of the much more abundant DU23 (Harrison-RT) which may not be representative of this small and unique population.
- Climate change is expected to result in a significant advance in the spring freshet, which can significantly impact migration conditions and spawning habitats. Considerable research is needed to understand the implications of changes in timing and duration of the spring freshet, and how changes in flows and temperatures will affect future generations of FRS. There have been major losses in forest cover in the Fraser River drainage through logging, wildfires, and pest infestations, which have led to significant modifications to catchment surfaces. Research is required to address watershed rehabilitation and restoration, while taking into account climate change, fire and pest resilience and future fibre supplies.
- Discharge thresholds have been proposed for FRS depending on the location of spawning grounds (e.g. Macdonald et al. 2010), yet there are limited studies describing these thresholds for FRS at the DU-level. Future research on discharge thresholds may aid in identifying the most at-risk DUs encountering migratory challenges from high flows, and help inform mitigation efforts to improve or protect habitat and environmental conditions.

C.2. MARINE HABITAT

There is considerable uncertainty surrounding FRS habitat use once they leave freshwater and enter the Pacific Ocean. Our limited knowledge of movements and behaviour in the open ocean, and our inability to monitor fish over large geographical areas greatly inhibits our ability to estimate the impacts on FRS, particularly at the DU-level. There is some, albeit inconsistent data from distant fisheries that have provided some insight on seasonal distributions in the ocean, yet this information is highly uncertain. Research is needed to improve our knowledge of FRS movements in the marine environment distribution in order to better manage fishing activities and marine protected areas.

C.3. AQUACULTURE

Net-pen aquaculture has long been identified as a potential contributor to declines in FRS (e.g. pollution, disease transmission, wasted feed, feces and water quality of surrounding area), and the recent decision to phase out net-pen aquaculture in the Discovery Islands will likely reduce this threat. There are likely lasting impacts on local ecosystems following the shut-down of these facilities, and there are still net-pen facilities in other areas of coastal BC. Future research is needed to investigate the long-term environmental impacts from net-pen aquaculture, in addition to potential impacts from remaining facilities.

C.4. MINING

The Mount Polley tailings pond breach has had unknown, but undoubtedly negative effects on FRS and other species within the Quesnel Lake ecosystem. Future research and monitoring is needed to determine the environmental impacts within and downstream of Quesnel Lake, and the effects on FRS and other aquatic species

C.5. FISHING

Many sources of uncertainty were identified surrounding the impacts of fishing on FRS. Sockeye inhabit vast geographic areas, are subject to transboundary fisheries, and catch monitoring is not standardized between regions and fisheries. Research is needed to:

- better design and implement catch-monitoring programs using the same standards for all fisheries (see Beauchamp et al. 2019);
- address our limited ability to properly assess lower abundance fish stocks with low sample sizes (stock ID, catch, abundance, etc.);
- assess the impacts of illegal fishing activity through increased enforcement and monitoring;
- better understand the impacts from non-retention fisheries, including studies that investigate mortality rates from fishery to spawning grounds (i.e. more information than previous 24-hour holding period experiments following fisheries encounters;
- investigate the relationship between gear-specific release mortality for in-river fisheries and in-river temperatures, with the goal of better-informing in-season fishing decisions;
- investigate the impacts of illegal, and unreported fishing activity In both the freshwater and marine environments.

C.6. PREDATOR AND PREY DYNAMICS

- It is likely there will be a continuing shift in predator and prey species composition with climate change. There is a need to better characterize these changes and understand the implications to future FRS populations. Examples of this are shifts in zooplankton distribution due to warming ocean temperatures, and the recent increase of coastal jellyfish populations, both of which could change prey availability;
- Research is needed to investigate the impacts of pinniped predation on FRS, particularly for low-abundance DUs in which predation effects could be significant.

C.7. ENHANCEMENT

- The Big bar landslide has led to high levels of pre-spawn mortality, particularly for the earliest-timed DUs (DU20 Takla-Trembleur-EStu, DU2 Bowron-ES, DU22 Taseko-ES). Following two subsequent years of record-low returns hatchery enhancement programs were initiated in an attempt to prevent extinction of these populations. Research will be needed to determine future genetic impacts from these activities.

- Our current understanding of FRS nursery lake habitat was identified as a source of uncertainty due to limited monitoring efforts, and there is a need to determine the suitability and potential impacts of lake fertilization programs. Recent proposals for nutrient subsidy programs in the Fraser River watershed have been put forth (e.g. Adams, Takla-Trembleur), yet their implementation, effectiveness at current abundances, and sustainability is not well-defined, in addition to having potential unintended ecological consequences. Further research is needed to investigate the potential for system-specific lake fertilization programs within FRS nursery lakes.

C.8. POLLUTION

The effects of pollution at all life stages were identified as a major knowledge gap for FRS. There are many sources of pollution within the Fraser River watershed and along the Pacific coast (both current and historic) that can impact FRS, many of which have been shown to have negative effects on various Pacific salmon populations in both Canada and the US. Research is needed to further our knowledge of the many sources and effects of contaminants on FRS for future mitigation and recovery planning.

C.9. BIG BAR LANDSLIDE

The Big Bar landslide has had major impacts on the 2019 and 2020 returns for FRS that spawn above the slide. Major efforts have been underway at the site since the landslide occurred, and a fish ladder is being constructed to allow passage for future generations. Research will be necessary to determine the impacts of the slide on cohorts that encountered it and their progeny, and efficacy of passage through the newly constructed fish ladder. This will likely be more important in future years with increasing variability in flow patterns in the mainstem Fraser River due to modifications to catchment surfaces and from climate change.