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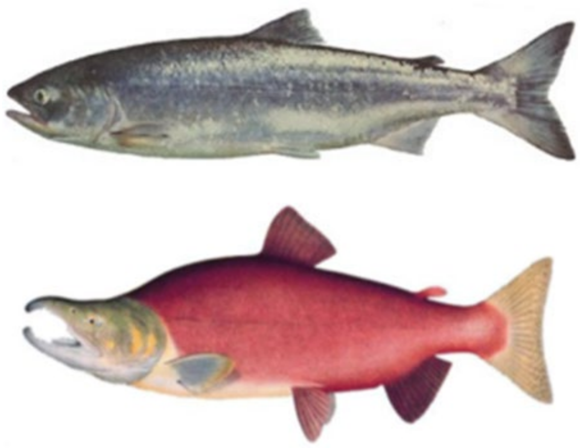
Science Advisory Report 2022/003

RECOVERY POTENTIAL ASSESSMENT FOR FRASER RIVER SOCKEYE SALMON (*ONCORHYNCHUS NERKA)* – NINE DESIGNATABLE UNITS – PART 2: HABITAT, THREATS ASSESSMENT, MITIGATION, AND ALLOWABLE HARM



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

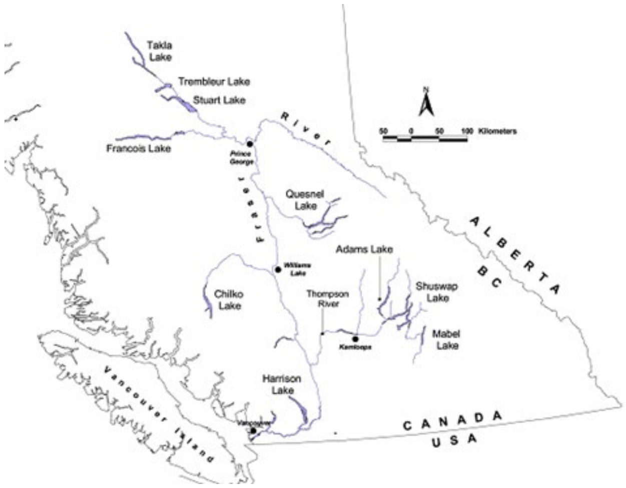


Figure 1. Map of the Fraser River watershed, British Columbia (BC), Canada.

Context:

The nine populations of Fraser River Sockeye Salmon assessed in this document were designated as either Threatened or Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2017. Fisheries and Oceans Canada (DFO) Science branch is responsible for conducting a Recovery Potential Assessment (RPA) to provide science advice to inform the potential addition of these populations to Schedule 1 of the Species at Risk Act (SARA). The advice in the RPA will be used to inform both scientific and socio-economic aspects of the listing process, development of a recovery strategy and action plan, support decision making with regards to the issuance of permits or agreements, and the formulation of exemptions and related conditions. The advice generated via this process will update and/or consolidate any existing advice regarding these populations of Fraser River Sockeye Salmon.

This Science Advisory Report is from the March 16-18, 2021 regional peer review on Recovery Potential Assessment – Fraser River Sockeye Salmon (Oncorhynchus nerka) – Ten Designatable Units. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule](#) as they become available.

January 2022

SUMMARY

This is the second of two parts of a Recovery Potential Assessment (RPA) for 9 Designatable Units (DUs) of Fraser River Sockeye Salmon (FRS). The objective for this portion of the RPA was to assess threats that may be limiting the survival and recovery of these DUs, discuss scenarios for mitigation of these threats, and to provide recommendations for allowable harm based on the collective results from both parts of the RPA.

- The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed twenty-four FRS DUs in 2017. Ten DUs were assessed as either Threatened or Endangered. This RPA addresses nine of those DUs; one DU was assessed in a separate RPA process (DU6 Cultus-L). Declining trends in abundance have continued for these DUs since the COSEWIC assessment. The following DUs were assessed:
    - DU2 Bowron-ES (Endangered)
    - DU10 Harrison (U/S)-L (Endangered)
    - DU14 North Barriere-ES (Threatened)
    - DU16 Quesnel-S (Endangered)
    - DU17 Seton-L (Endangered)
    - DU20 Takla-Trembleur-EStu (Endangered)
    - DU21 Takla-Trembleur-S (Endangered)
    - DU22 Taseko-ES (Endangered)
    - DU24 Widgeon-RT (Threatened)
- Redds, the spawning nests constructed by Pacific salmon and other fish species, meet the definition of a “residence” under the *Species at Risk Act* (SARA).
- A threats calculator based on the International Union for Conservation of Nature (IUCN) threats classification system was used to estimate the population-level impacts over the next three generations from many ongoing and future anthropogenic threats.
- The overall threat ranking ranged between High to Extreme for all DUs based on the number and severity of the threats. Common threats to all DUs were climate change, geological events, fishing, pollution, ecosystem modifications, problematic species, and hatchery competition.. Individual DUs are experiencing a unique combination of threats based on the location of spawning grounds and migration timing that resulted in different overall threat rankings.
- The landslide in the mainstem Fraser River near Big Bar poses a specific threat to five Endangered DUs that spawn above the slide: DU2 (Bowron-ES), DU16 (Quesnel-S), DU20 (Takla-Trembleur-EStu), DU21 (Takla-Trembleur-S), and DU22 (Taseko-ES). The challenging migratory conditions created by the landslide has led to high levels of adult en-route mortality, particularly for the earliest-timed DUs (i.e. DU2, DU20, DU22). Even with appropriate mitigation, DU2, DU20 and DU22 face persistent challenges into the future. Impacts of the landslide on juvenile salmon out-migration are being investigated.
- Regulatory responsibilities for mitigations lie with multiple jurisdictions. Mitigating the numerous complex, and often interrelated, threats facing these DUs will be extremely challenging, especially as many threats are exacerbated by climate change.
- Based on the collective results from Part 1 and 2 of this RPA, the following allowable harm statements were made:

- for DU2 Bowron-ES and DU20 Takla-Trembleur-EStu, the only activities allowed that cause mortality should be 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.
- for DU10 Harrison (U/S)-L, DU14 North Barriere-ES, DU16 Quesnel-S, DU17 Seton-L, DU21 Takla-Trembleur-S, and DU22 Taseko-ES, the only activities allowed that cause mortality should be those that are in support of the *survival and recovery* of the DU, and all sources of anthropogenic harm should be reduced to the maximum extent possible.
- for DU24 Widgeon-RT, this population is naturally at low levels and is susceptible to harm even if steps are taken to minimize mortality. As such, the only activities allowed that cause mortality should be those that are in support of the *persistence* of the DU, and all sources of anthropogenic harm should be limited to the maximum extent possible.

INTRODUCTION

Rationale for Recovery Potential Assessment

After the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses an aquatic species as *Threatened, Endangered* or *Extirpated*, Fisheries and Oceans Canada (DFO), as the responsible jurisdiction for aquatic species under the *Species at Risk Act* (SARA), undertakes several actions to support implementation of the Act. Many of these actions require scientific information on the current status of the species, threats to its survival and recovery, and the species' potential for recovery. Formulation of this scientific advice has typically been developed through a Recovery Potential Assessment (RPA) following the COSEWIC assessment. This timing allows for the consideration of peer-reviewed scientific analyses into SARA processes, including the decision whether or not to list a species on Schedule 1, and during recovery planning if the species is listed.

Declining trends in abundance have been observed for many FRS populations over the last several decades. Almost half of FRS stocks have been placed in the Wild Salmon Policy (WSP) Red status zone (Grant and Pestal 2012; DFO 2018), and COSEWIC has recently (2017) assigned many of those stocks a status of either *Endangered* (n=8) or *Threatened* (n=2). 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 (COSEWIC 2017; Cultus Lake (DU6) assessed separately). These 9 DUs are widely distributed throughout the Fraser River watershed, and include stocks from all run-timing groups, or Management Units (MU; Table 1).

Table 1. Fraser Sockeye Salmon Designatable Units (DU) covered in this RPA, and their corresponding fisheries Management Unit (MU) based on run-timing.

Management Unit (MU)	Designatable Unit (DU)	COSEWIC Status
Early Stuart	DU20 Takla-Trembleur-EStu (Early Stuart)	Endangered
Early Summer	DU2 Bowron-ES	Endangered
	DU14 North Barriere-ES (Upper Barriere)	Threatened
	DU22 Taseko-ES	Endangered
Summer	DU16 Quesnel-S	Endangered
	DU21 Takla-Trembleur-S (Late Stuart)	Endangered
	DU24 Widgeon-RT	Threatened
Late	DU10 Harrison (U/S)-L (Weaver)	Endangered
	DU17 Seton-L (Portage)	Endangered

This RPA is the second of two parts. This first part of the RPA (DFO 2020) covers quantitative analysis of recovery targets, probability of achieving recovery targets, and mitigation effects (Elements 12,13,15,19-21). This report addresses the remaining Elements outlined in the Terms of Reference for completion of RPAs for Aquatic Species at Risk (DFO 2014), which includes: summaries of FRS biology, abundance, distribution and life history parameters (Element 1-3); descriptions of FRS habitat and residence requirements at all life stages (Element 4-7); assessment and prioritization of threats and limiting factors to the survival and recovery of FRS (Element 8-11); descriptions of suitable habitat supply and whether habitat requirements are met (Element 14); discussions of scenarios for mitigation of threats and alternatives to activities (Element 16-18); and a final assessment of allowable harm to evaluate the maximum human-induced mortality and habitat destruction that the species can sustain without jeopardizing its survival or recovery (Element 22).

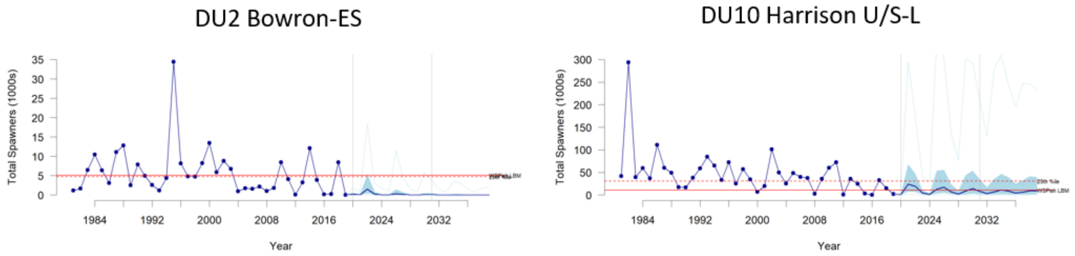
Biology, Abundance, Distribution and Life History Parameters

FRS 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 2017). The majority of FRS are considered to be lake-type variants based on their freshwater life history, in which they rear for one or more years in a nursery lake before migrating to sea. Ocean-type Sockeye disperse downstream shortly after emergence and rear for a variable, and often shorter period of time in side channels and sloughs in the lower Fraser River before migrating to sea (Gilbert 1913; Nelson 1968; COSEWIC 2017). DU24 (Widgeon-RT) is the only ocean-type population considered in this RPA. It is noted that while DU24 is referred to as a river-type population it is not a true river-type population; these fish migrate to sea in their first year and do not overwinter in freshwater stream habitat, and have similar life-histories to other ocean-type Sockeye along the Pacific Coast. 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-

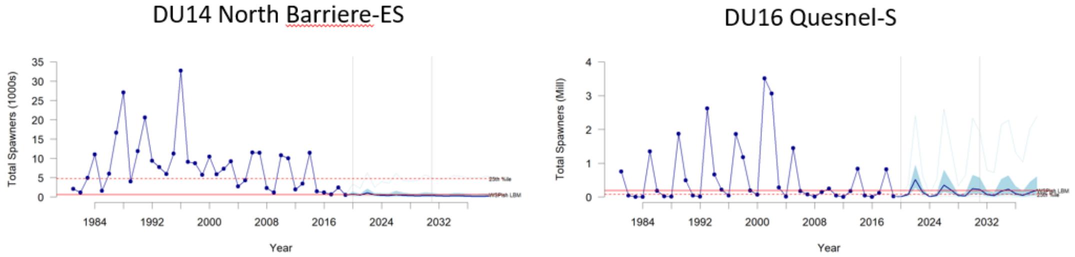
4_2) (Grant et al. 2011; Macdonald et al. 2020). All lake-type DUs considered in this RPA have a generation time of 4 years. Ocean-type variants return to spawn as either three or four year old fish (age-3_1 and age-4_1, respectively), and DU24 (Widgeon-RT) is composed primarily of age-3 fish.

The 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). Data collection on the spatial distribution of spawning FRS began in 2001, and since 2008 spatial data on spawning distribution has been collected annually for all DUs in the Fraser River basin. However, water clarity and depth of spawning likely impair observations of habitat use for many DUs, therefore estimates of the spatial extent of spawning based on these observations should be considered minimums (de Mestral Bezanson et al. 2012; COSEWIC 2017). Many FRS DUs contain multiple spawning sites within the DU area, some of which are not surveyed for fisheries enumeration, or have been inconsistently surveyed through time. As a result, abundance estimates for some DUs are based off a subset of streams within a larger DU area. Table 2 lists spawning streams within each DU, but does not necessarily contain all FRS-bearing streams within the DU.

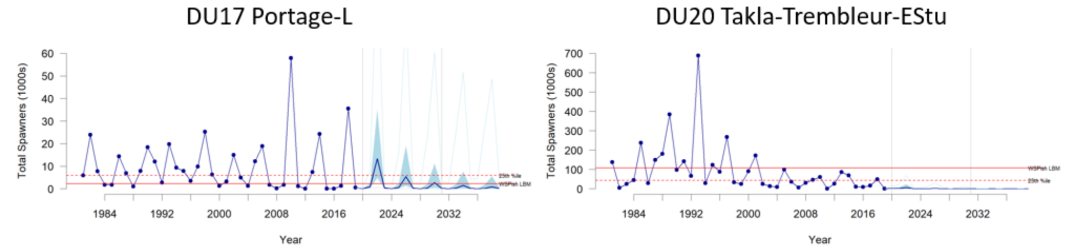
Enumeration of FRS stocks is conducted using a variety of techniques including fence counts, mark-recapture studies, sonar systems, and aerial/ground surveys, and varies significantly between systems. Seven of the DUs (DU2 Bowron-ES; DU10 Harrison (U/S)-L; DU14 North Barriere-ES; DU16 Quesnel-S; DU17 Seton-L; DU20 Takla-Trembleur-ES; DU21 Takla-Trembleur-S;) are considered to have high quality abundance data from their respective enumeration programs, in addition to productivity data that enables forward projections for abundance into future generations. The other two DUs (DU22 Taseko-ES; DU24 Widgeon-RT) are low abundance stocks (<2000 individuals between 2001-2020), abundance estimates are much more uncertain, and productivity data does not exist to provide forward abundance projections. Figure 2 displays abundance trends for FRS DUs considered in the RPA between the 1981 to 2018 brood years. Persistent sample locations, data quality, enumeration methods, and the Index of Area of Occupation (IAO) for each FRS DU is listed in Table 2.


DU2 Bowron-ES

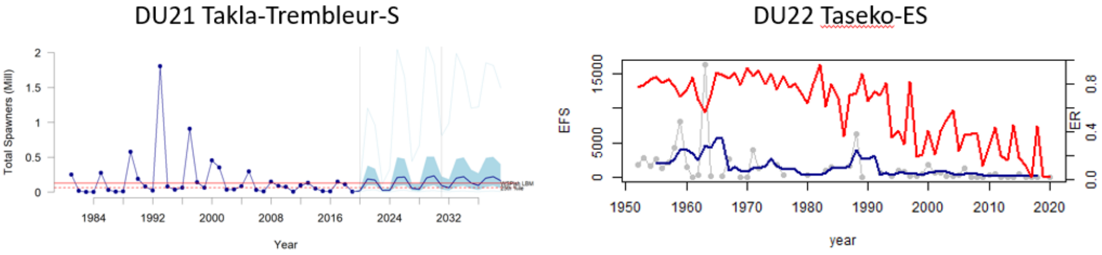
DU10 Harrison U/S-L


DU14 North Barriere-ES

DU16 Quesnel-S


DU17 Portage-L

DU20 Takla-Trembleur-EStu


DU21 Takla-Trembleur-S

DU22 Taseko-ES

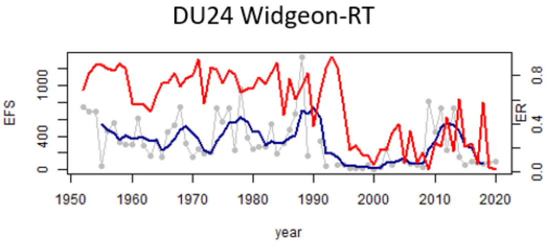

DU24 Widgeon-RT

Figure 2. Abundance estimates for FRS DUs considered in RPA, including forward abundance projections where productivity data were available (7 of 9 DUs). Estimates of total spawners (blue line), the 25th percentile of historical abundance (dashed red line), and lower WSP abundance benchmark (solid red line) are displayed for brood years 1981-2018. Abundance estimates are projected 3 generations into the future (grey vertical lines); the blue line represents the estimated median abundance, the blue shaded portion represents the 25th to 75th percentiles of abundance, and the light blue line represents the 95th percentile of abundance. For DU22 Taseko-ES and DU24 Widgeon-RT, no productivity data were available to provide forward abundance projections; these figures depict estimates of effective female spawners (blue line) and a proxy exploitation rate (red line) over the entire time series (1952-2020).

Table 2. Sampling sites for abundance estimates, survey methods, data quality, and Index of Area of Occupation (IAO) for FRS DUs assessed in this RPA.

Designatable Unit	Principle Spawning Locations	Data Quality	Survey Methods	IAO (km^2)
DU2 Bowron-ES	Bowron R	Good	Aerial Fence	16
DU10 Harrison-L	Weaver Ch Weaver Cr	Good	Peak Live & Cumulative Dead Mark Recapture Carcass Census Fence	4
DU14 North Barriere-ES	Barriere R (upper)	Good	Peak Live & Cumulative Dead	20
DU16 Quesnel-S	Horsefly R Mitchell R McKinley Cr Penfold Cr	Very Good	Peak Live & Cumulative Dead Mark Recapture Fence Sonar	352
DU17 Seton-L	Portage Cr	Good	Visual	20
DU20 Takla-Trembleur-EStu	Forfar Cr Gluske Cr O'Ne-ell Cr Van Decar Cr	Very Good	Peak Live & Cumulative Dead Mark Recapture Fence	428
DU21 Takla-Trembleur-S	Middle R Tachie R Kazchek Cr Kuzkwa Cr	Very Good	Peak Live & Cumulative Dead Mark Recapture Fence	164
DU22 Taseko-ES	Taseko L	Fair	Carcass Census	24
DU24 Widgeon-RT	Widgeon Sl	Good	Peak Live & Cumulative Dead	4

Habitat and Residence Requirements

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 period (Mote et al. 2003). 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; the latter not considered in this RPA).

Spawning and Egg Incubation

FRS require suitable freshwater habitat for spawning and egg incubation. 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). 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). 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 2017).

Fry and Juvenile Rearing Habitat

For lake-type variants, newly emerged Sockeye 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 2017). Juvenile lake-type FRS require nursery 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 River.

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 2017). 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). Most lake-type FRS leave the Strait of Georgia to enter the open ocean via Johnstone Strait to the north, 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 2017). 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).

Ocean Rearing Habitat

Following their entrance into the ocean, lake-type FRS 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). 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[1]; 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. 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).

Adult Freshwater Migratory Habitat

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 reduce reductions in cardiorespiratory system function may impede migration (Eliason et al. 2011). For Sockeye Salmon in general, water temperatures above ~18°C increase en route 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. Depending on their return timing and distance to spawning grounds, FRS require stable flows and buffering from high temperatures during their upstream migration.

Spatial Configuration Constraints

The majority of FRS are not impacted by hydroelectric development. There are two major hydroelectric developments that impact FRS covered in this RPA: the Kenney Dam on the

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[1] Johnson, B. 2016. Development and evaluation of a new method for assessing migration timing of juvenile Fraser River sockeye salmon in their early marine phase. Undergraduate Thesis, University of Northern British Columbia.

headwaters of the Nechako River (DU20, DU21); and Seton Dam near the confluence to the mainstem Fraser and Seton rivers (DU17). 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 Seton River), and near Big Bar in the mainstem Fraser. Landslides 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.

Concept of Residence

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”. Redds, the spawning nests constructed by Pacific salmon and other fish species, are considered residences under this definition in the event of listing as *Threatened, Endangered or Extirpated* under SARA.

ASSESSMENT

Threats and Limiting Factors to Survival and Recovery

Threat categorization for FRS is 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. This threat classification system was used to define broad categories of threats, and the final threat assessment follows DFO (2014) guidance to the extent possible in the context of limited data and information on threats to FRS within Canadian waters. A working group assessed threats using a COSEWIC threats calculator tool prior to the Regional Peer Review. The information and rankings from the initial COSEWIC-style assessment by the working group were then used to convert the assessment into the DFO (2014) standardized assessment method. Climate change, geological events, fishing, pollution, ecosystem modifications, problematic species, and hatchery competition were identified as the leading threats to all FRS DUs.

Climate Change

Climate change is expected to impact all FRS at all life-stages and in all habitats. Warmer mean ocean temperatures, reduced sea ice extent, and increased ocean acidification are all contributing to shifting marine habitat conditions, threatening FRS through shifts in zooplankton distribution, ocean productivity, nutrient availability, metabolic requirements, and intensification of predation by other species. Marine heatwaves such as “The Blob” between 2013-2016, and more recent warm water anomalies in 2019 and 2020, are becoming more common and have caused unprecedented shifts in marine ecosystems along the Pacific coast of North America.

Increasing air temperatures, advancing spring freshet, reduced spring snow packs, and receding glaciers have greatly impacted the hydrologic regime of the Fraser River watershed, creating challenging migration conditions for FRS that continue to lead to high levels of en-route mortality. Environmental conditions in nursery lakes are also changing with the shifting climate, which is particularly important for the FRS juvenile rearing stage (Grant et al. 2019). The occurrence of extreme weather events such as droughts, heat waves, storms and floods are also projected to increase in frequency with the changing climate, all of which have significant negative implications for FRS.

Geological Events

Landslides can block migration of both adult and juvenile FRS, destroy habitat, and alter habitat conditions by introducing unnaturally high concentrations of sediment. 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. 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. Additional geological events that impact FRS have also occurred downstream of the Big Bar landslide. The 2015 and 2016 landslides at Whitecap Creek (within DU17 Seton-L) deposited large amounts of sediment into Portage Creek, that prevented outflow from Anderson Lake and caused flooding around the lakeshore (BGC 2018). In 2010, a landslide occurred at Meager Creek 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 from DU10 Harrison (U/S)-L where juveniles rear.

Ecosystems Modifications

Modifications to ecosystems through activities such as water extraction, forestry, and development, or through major wildfires, can greatly reduce catchment areas within a watershed and lead to significantly altered runoff dynamics. The resulting impacts on flow regimes and stream temperatures have both led to degradation of habitat in some DUs and created challenging migration conditions as far downstream as the lower Fraser River. Future salvage logging operations, which are not currently bound to the same regulations as timber harvest, are of particular concern following major fires and pest infestations in BC.

Pollution

Pollution within the Fraser River watershed is considered to be a threat to all Pacific Salmon species. Many contaminant sources exist within both the freshwater and marine habitat of FRS. Pacific salmon are, in general, particularly susceptible to the effects of environmental contamination as extensive migrations, physiological transformations, and rapid growth rates lead to high rates of exposure and accumulation of contaminants (Ross et al. 2013). This exposure can lead to impairment of salmonid olfactory function, migratory behaviour, and immune system function, which may reduce individual survival, but can also reduce reproductive success and productivity of a population. There are, however, challenges in understanding the effects of individual contaminates on FRS as many are persistent in the environment, may travel long distances, and have a tendency to accumulate in sediments and food chains from multiple sources (Garette 1980; Gray and Tuominen 1999). All pollution threat categories were anticipated to pose a Low-Medium level of risk to all FRS DUs with the exception of garbage and solid waste. It is anticipated that the threat from garbage and solid waste, which includes micro-plastics and lost or abandoned fishing gear, has some impact on FRS and that the overall impacts are negative but not well understood.

Fishing

There are both targeted and non-targeted fisheries that intercept FRS, most of which occur in coastal Canadian and US waters, and in the lower Fraser River during their adult return migration (Grant et al. 2021). These fisheries include: First Nations food, social, and ceremonial fisheries; U.S. Tribal ceremonial and subsistence fisheries; recreational fisheries; Canadian commercial fisheries (including First Nations economic opportunity); U.S. All Citizen and Tribal commercial fisheries; and test fisheries operated both by DFO and the Pacific Salmon Commission (PSC). All FRS DUs covered in this RPA are expected to be impacted by some combination of these fisheries, as the majority co-migrate with more abundant FRS stocks considered to be Not at Risk by COSEWIC (e.g. DU3/4 Chilko ES/S; DU18/19 Shuswap L/ES) that are the main drivers of harvest at the MU level. DU20 Takla-Trembleur-EStu is protected by a window closure; however, there is concern that the actual mortality rates could be higher than estimated due to management uncertainty, illegal fishing activities, and bycatch mortality.

Problematic Species

There a variety of native and non-native species that impact FRS through predation, competition, habitat degradation or alteration, and disease in both the freshwater and marine environments. Threats and associated species of note include: predation by pinnipeds (e.g. Harbour Seals, Stellar Sea Lions, California Sea Lions); predation and competition by spiny ray and other invasive fishes (e.g. Smallmouth/Largemouth Bass, Yellow Perch, Pumpkinseed, Northern Pike); habitat destruction and alteration (e.g. European Green Crab); and exposure to pathogens and disease through anthropogenic activities (e.g. net-pen aquaculture, fish hatcheries). Due to differences in run-timing and the location of spawning habitat some FRS DUs are likely at greater risk from problematic species, but all DUs are anticipated to have some level of impact.

Hatchery Competition

Increasing abundances of hatchery salmon across the North Pacific, and in particular pink salmon, have been linked to a trophic cascade in epipelagic waters leading to fewer zooplankton, 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). Pink Salmon abundance 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). 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 (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, yet there is evidence that indicates increases in Chum Salmon abundance may also lead to adverse competitive interactions with FRS (Johnson and Schindler 2009). All FRS 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.

Natural Limiting Factors

Natural limiting factors are defined as “non-anthropogenic factors that, within a range of natural variation, limit the abundance and distribution of a wildlife species or a population” (DFO 2014). Natural limiting factors or processes may be exacerbated by anthropogenic activities and can then become a threat. By default, a natural limiting factor would be scored as having a “Low”

Threat Risk in the calculator unless there are other factors that are exacerbating natural levels of variation or impacts to a population. Almost all of the natural limiting factors are affected by anthropogenic-induced climate change or landscape-level human activities. Natural limiting factors are intertwined with existing threats and impacts, and for FRS include: the biological and physiological limits of Sockeye Salmon; predation at all life stages; inter/intra-specific competition in both marine and freshwater environments; and a variety of natural pathogens and/or diseases.

Table 3. 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

Habitat Supply

While freshwater habitat was described in the RPA (Elements 4-6), 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. This is highlighted as a source of uncertainty and more research is needed, yet it will require considerable effort and funding to investigate, monitor, and quantify habitat supply within large geographic areas of the Fraser River watershed. Table 4 displays available habitat metrics for each DU, where available.

It is 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 and unique ocean-type population that was assigned a status of Threatened by COSEWIC due to its low abundance (<1000 individuals) 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.

Table 4. Habitat characteristics for FRS DUs considered in this RPA. Migration distance is estimated using linear in-stream distance from the mouth of the Fraser River to spawning habitat; nursery lake habitat metrics reported in (Shortreed et al. 2001); IAO metrics are reported in (COSEWIC 2017).

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

Mitigation of Threats and Alternatives to Activities

The 9 FRS DUs considered in this RPA utilize a vast array of habitat types including much of the Fraser River watershed, estuary, and both nearshore and offshore marine habitats. There is considerable diversity between DUs, both ecologically, and from the perspective of the nature and severity of anthropogenic and natural threats to DU persistence. Consequently, a large number of potential threats were identified in Element 8 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, occur over large geographical areas, result in cumulative effects, and are exacerbated by climate change. Considerable knowledge gaps and sources of uncertainty are associated with many of these threats (e.g. climate change, ecosystems modifications, fishing, pollution), making it extremely challenging to link and quantify changes in abundance to specific mitigation activities, particularly at the DU level. A high-level inventory of mitigation activities was developed for the DUs assessed in this RPA, providing descriptions of activities and techniques that could generally be employed to mitigate the threats identified in Element 8. A full assessment of mitigation options will require DU-specific analysis due to the diversity in ecosystems, life histories, and range of threats. In most cases it will not be possible to quantitatively evaluate the possible benefits of mitigation measures on productivity or survivorship due to the lack of basic life history and habitat use information, and population data.

Table 5 lists a range of mitigation actions to address the threats identified in Element 8. A brief description of the threat in the context of Sockeye Salmon is provided along with the most likely pathway of effect on DU status. Here “habitat” refers to the definition as stated in the *Fisheries Act*: water frequented by fish and any other areas on which fish depend directly or indirectly to carry out their life processes, including spawning grounds and nursery, rearing, food supply and migration areas. No attempt has been made to prioritize mitigation options by DU, however, the threat tables in DFO (2020) contain DU-specific ratings for each threat that may provide some guidance. Mitigation options will vary in their potential to affect recovery, as well as their cost and feasibility; these factors are also not considered here, and will require DU-specific analyses.

Table 5. Possible mitigation strategies to address threats to FRS identified in Element 8.

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

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 summarized 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 in the current review. This section summarizes findings from both RPA documents for each FRS DU, and provides final allowable harm statements 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 2014). 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 2014). Two recovery targets were presented for FRS in DFO (2020):

- **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);
- **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, and in some cases, reaching Recovery Target #1 is also unlikely given current conditions. Preliminary results from 2020 spawner return data continue to support these conclusions.

This section includes the combined results of both parts of this RPA process. A set of “recovery plots” was generated illustrating the threats identified in Element 8, and the probability of each DU reaching Recovery Target #1 and #2 under current, and a range of potential future productivities and exploitation rates (ERs; Figures 2-10). 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) on the adult return. It is noted these plots were generated using the methods described in (DFO 2020) using three additional years of data (2016-2018) since Part 1 of the RPA was completed, and include updated assumptions surrounding the impacts of Big Bar (Pestal et al. in press). The entire lower range of future productivities (i.e., 10-50% below current productivity) is considered plausible given observed rates of decline over the past three generations. 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 but is not intended to reflect near-future productivity trends.

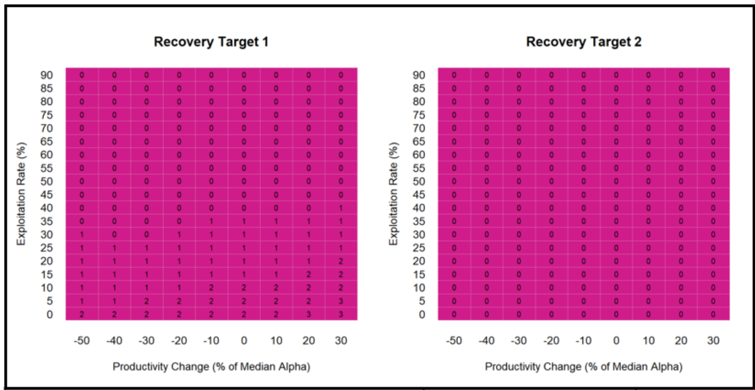
Based on the collective results of this RPA, **it is recommended for DU2 Bowron-ES and DU20 Takla-Trembleur-EStu that the only activities allowed that cause mortality are those that are in support of the survival of the DU, and all sources of anthropogenic harm should be reduced to the maximum extent possible.**

For all other lake-type DUs (DU10 Harrison U/S-L; DU14 North Barriere-ES; DU16 Quesnel-S; DU17 Seton-L; DU21 Takla-Trembleur-S; DU22 Taseko-ES), **it is recommended 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.**

For DU24 Widgeon-RT, this population is naturally at low levels and is susceptible to harm even if steps are taken to minimize mortality. As such, **it is recommended 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 limited to the maximum extent possible.**

The following series of recovery plots (Figures 3 – 11) summarizes the results of the threats assessment, and quantitative analysis of recovery targets for DUs in which stock-recruit data were available. Note the top and bottom two categories for “Likelihood of Reaching Recovery Target” are grouped together (i.e. Virtually Certain and Very Likely (90-100%); Very Unlikely and Exceptionally Unlikely (0-10%)) for simplicity, as the recommendations for cases that fall within the upper and lower bounds of these categories (0-1% and 99-100%) are the same as for the grouped categories.

DU2 Bowron-ES



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

Recovery Target 2

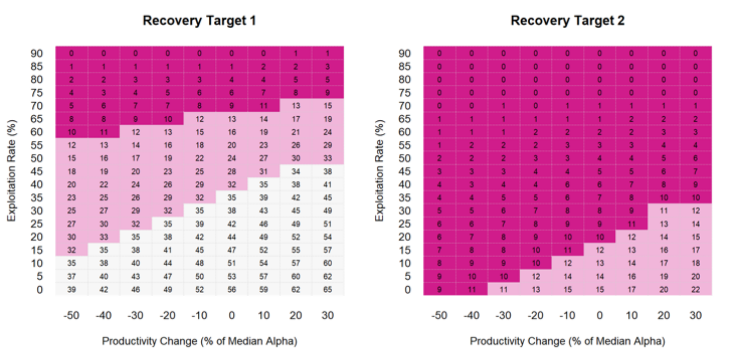
Exploitation Rate (%)	-50	-40	-30	-20	-10	0	10	20	30
90	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0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

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 3. Summary of threats assessment and probability of DU2 Bowron-ES reaching recovery targets.

DU10 Harrison (U/S)-L



Recovery Target 1

Exploitation Rate (%) \ Productivity Change (% of Median Alpha)	-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

Recovery Target 2

Exploitation Rate (%) \ Productivity Change (% of Median Alpha)	-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

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 4. Summary of threats assessment and probability of DU10 Harrison U/S-L reaching recovery targets.

DU14 North Barriere-ES

Recovery Target 1

Exploitation Rate (%) \ Productivity Change (% of Median Alpha)	-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

Recovery Target 2

Exploitation Rate (%) \ Productivity Change (% of Median Alpha)	-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

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 5. Summary of threats assessment and probability of DU14 North Barriere-ES reaching recovery targets.

DU16 Quesnel-S

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

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	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

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	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 6. Summary of threats assessment and probability of DU16 Quesnel-S reaching recovery targets.

DU17 Seton-L

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

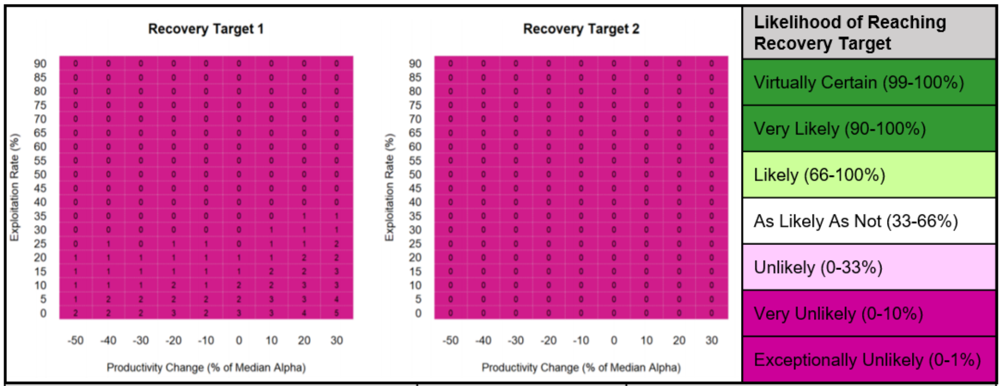
Productivity Change (% of Median Alpha)

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 7. Summary of threats assessment and probability of DU17 Seton-L reaching recovery targets.

DU20 Takla-Trembleur-EStu



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	1	1
30	0	0	0	0	0	0	1	1	1
25	0	1	0	1	1	0	1	1	2
20	1	1	1	1	1	1	1	2	2
15	1	1	1	1	1	1	2	2	3
10	1	1	1	2	1	2	2	3	3
5	1	2	2	2	2	2	3	3	4
0	2	2	2	3	2	3	3	4	5

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

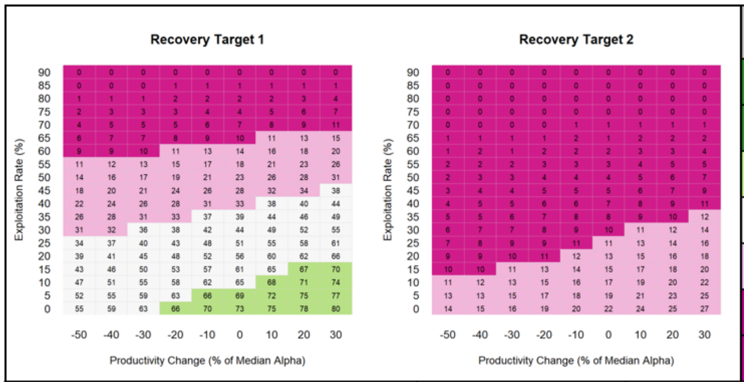
Productivity Change (% of Median Alpha)

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 8. Summary of threats assessment and probability of DU20 Takla-Trembleur-EStu reaching recovery targets.

DU21 Takla-Trembleur-S



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%

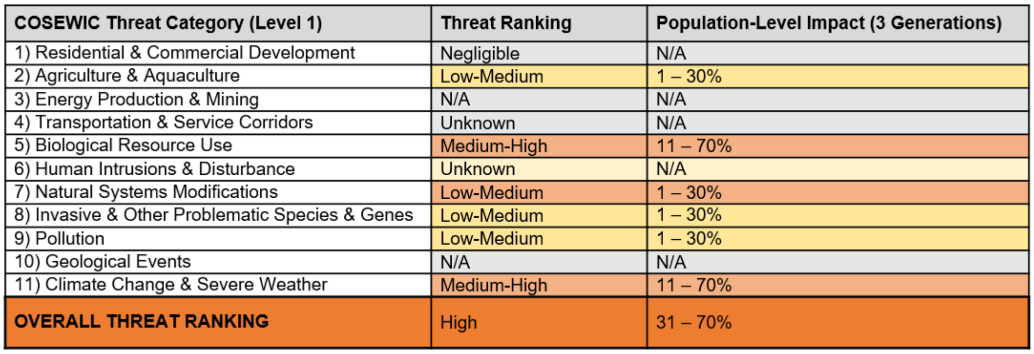
Figure 9. Summary of threats assessment and probability of DU21 Takla-Trembleur-S reaching recovery targets.

DU22 Taseko-ES

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 10. Summary of threats assessment for DU22 Taseko-ES.

DU24 Widgeon-RT



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 11. Summary of threats assessment for DU24 Widgeon-RT.

Sources of Uncertainty

There is uncertainty associated with the estimation of run size, exploitation rate, spawning escapement, and in-river mortality. This uncertainty is inherently larger for smaller stocks as lower precision spawning ground estimation methods are used for escapements that are anticipated to be less than 75,000 fish, and smaller stocks by definition are encountered less frequently in test fisheries resulting in smaller sample sizes. Projections of future productivity ranges are based on historical relationships between spawning stock and recruitment, and it is currently unknown how representative these historical relationships are in a changing global climate.

- There is uncertainty surrounding FRS habitat use at all life-stages, and the supply and availability of suitable habitat within each DU. Seasonal fluctuations in environmental and hydrologic conditions can also alter the availability, quantity, and quality of all habitat types within a given DU, and current monitoring efforts are insufficient to capture these changes on an annual basis.
- There is uncertainty surrounding the severity and impact of threats identified in the threats assessment, and which threats are the key drivers of current population statuses. The cumulative impacts from these threats are also highly uncertain.
- There is uncertainty surrounding the efficacy or feasibility of the mitigation measures described in Table 5. Many of these strategies are broad and general to Pacific salmon conservation, and may not be applicable or appropriate for all FRS DUs. Further to this, considerable uncertainty is associated with many threats making it extremely challenging to link and quantify changes in abundance to specific mitigation activities, particularly at the DU level.
- There is uncertainty surrounding DU24 Widgeon-RT, the only non-lake-type population covered in the RPA. Despite being classified as a river-type population, this population is closer in life-history to ocean-type Sockeye Salmon in other regions that migrate to sea in their first year. We currently have a limited understanding of habitat use and behaviour for DU24 (Widgeon-RT), and much of our understanding comes from observations of the much more abundant DU23 (Harrison-RT) which may not be representative of this small and unique population.
- There is uncertainty surrounding the long term impacts from the Big Bar landslide. There were immediate, and significant negative impacts on FRS returning to spawn above the slide in 2019 and 2020, yet 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.

FUTURE RECOMMENDATIONS

- Research is needed to improve knowledge of DU-specific survival at each life history stage, which will allow for parsing out of marine versus freshwater mortality rates. This will improve the evaluation of potential mitigation measures.
- Research is needed to identify FRS habitat use and distribution in the marine environment, both during the juvenile and adult rearing life-stages. It will be important to identify FRS ocean distribution, and future shifts in ocean distribution, in order to link smolt-adult survival with environmental conditions that can aid in forecasting and generating long-term population projections.
- 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 and composition. Further to this, much of this information is based off research conducted in the late 1990s and early 2000s, and there is evidence to suggest environmental conditions have shifted in some lakes potentially impacting productivity and habitat supply. 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.
- DU-specific studies should be completed for the threats identified in this RPA, and potential mitigations to those threats. While many DUs share similar life histories, the watersheds within and among DUs are highly diverse ecologically and environmentally, and will require different strategies to promote recovery. Further to this, methods to evaluate and monitor potential mitigation measures at the DU level are needed. In some cases, quantitative modelling may be feasible, but in most situations a blend of quantitative analysis and structured expert assessment may be required.
- Research is needed to develop more selective and lower impact fishing methods for both targeted FRS fisheries, and non-targeted fisheries that intercept FRS as bycatch. This work also needs to include research on run timing and distribution of FRS stocks to reduce impacts on weaker DUs that co-migrate with more abundant stocks. On dominant years there is substantial pressure to harvest the most abundant FRS stocks (e.g. Chilko, Shuswap), and increased spatiotemporal information on the imperilled FRS DUs will aid in preventing further mixed-stock fishing effects.
- There is a need to conduct climate change vulnerability assessments for each DU, as this will identify which DUs are the most vulnerable to changes in climate and why. This will aid in the identification and prioritization of research, mitigation measures, and management actions.
- Research is needed to monitor the longer term effects of the Big Bar landslide, including changes in en-route mortality, age composition, individual fitness, overall population structure, and migration success of adults and juveniles. The collection of this information is vital to inform all future quantitative evaluation of Fraser Sockeye, including recovery success. Without it, any projections of Fraser Sockeye populations will be based on assumptions that are not supported by empirical evidence.
- There is a need to better understand the genetic structure of FRS at the DU and deme level, in order to support conservation enhancement measures that have been initiated for the

most imperilled DUs that spawn above the slide (DU2 Bowron-ES, DU20 Takla-Trembleur-EStu, DU22 Taseko-ES). There will likely be continued pressure for enhancement activities such as these, in the absence of sufficient genetic information to support these activities.

OTHER CONSIDERATIONS

- The assessment in this report was conducted at the individual DU level. However, management of fisheries occurs at the stock management unit (SMU) level for Fraser Sockeye and the DUs are also affected by fisheries targeting Chinook and Pink salmon. Similarly, interpretation and implementation of advice in this report should take into account both the narrow (individual DU) as well as the wider (SMU level and cross species) scope.
- The assessment in this report focused on nine Endangered and Threatened DUs. There are an additional five DUs which were identified as being of Special Concern by COSEWIC (2017). Quantitative evaluation of these Special Concern DUs in Part 1 of the RPA (DFO 2020) showed that two DUs (DU11 Kamloops-ES, DU12 Lillooet-Harrison-L) had poor recovery trajectories, similar to the Endangered and Threatened DUs presented in this report.

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SOURCES OF INFORMATION

This Science Advisory Report is from the March 16-18, 2021 regional peer review on Recovery Potential Assessment – Fraser River Sockeye Salmon (*Oncorhynchus nerka*) – Ten Designatable Units. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule]() as they become available.

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