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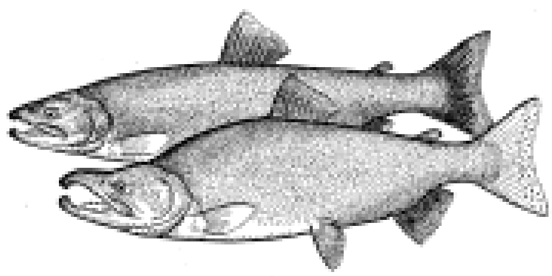
Pacific Region

Canadian Science Advisory Secretariat
Science Advisory Report 2018/042

RECOVERY POTENTIAL ASSESSMENT FOR THE SAKINAW LAKE SOCKEYE SALMON (*ONCORHYNCHUS NERKA*) (2017)



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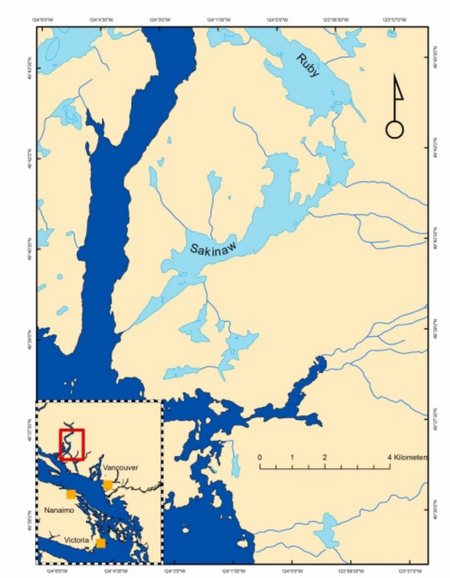

Figure 1. Sakinaw Lake (light blue) located on the Sechelt Peninsula, BC coast. Strait of Georgia is to the west (dark blue).

Context:

Sakinaw Lake Sockeye Salmon ("Sakinaw Sockeye") was reassessed in 2016 as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The reason for designation as Endangered was "This population experienced a very large decline in the 1980s and 1990s because of low ocean survival and over-fishing. Brood stock from Sakinaw Lake were maintained in a captive-breeding program that produced fry and smolts released into the lake beginning in 2000. Despite these introductions, almost no adults returned to the lake in 2006-2009. Smolts from the captive-breeding program continued to be introduced and adults returned to the lake in 2010 through 2014. Some of these fish spawned successfully on historical spawning beaches, demonstrating that the program was having some success in re-establishing the population. However, the number of wild-hatched fish is very small. Threats from development around the lake, low ocean survival, and the fishery continue."

DFO Science was asked to complete a Recovery Potential Assessment (RPA) to provide science advice to inform a listing recommendation for the addition of Sakinaw Sockeye Salmon to Schedule 1 of the Species at Risk Act (SARA). The advice in the RPA may be used to inform both scientific and socio-economic elements of the listing decision, as well as development of a recovery strategy and action plan, and to support decision-making with regards to the issuance of permits, agreements and related conditions, as per section 73, 74, 75, 77 and 78 of SARA should the species be listed.

This Science Advisory Report was generated by the 25-26 April 2017, regional Recovery Potential Assessment – Sakinaw Sockeye Salmon. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Sakinaw Lake Sockeye Salmon (*Oncorhynchus nerka*) is the Designatable Unit of anadromous Sockeye Salmon that spawns in Sakinaw Lake.
- Sakinaw Sockeye Salmon was first assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2002 as an emergency assessment and recommended as Endangered. The status was re-examined and confirmed in May 2003, and in another emergency reassessment status was confirmed in April 2006. As per section 24 of the Species at Risk Act (SARA), COSEWIC reviewed the classification in April 2016 and the status was confirmed as Endangered.
- Sakinaw Sockeye Salmon are now all descendants of re-introduced fish from the captive breeding program.
- COSEWIC included all intra-limital reintroductions as part of the wildlife species being assessed. Therefore, although the captive bred and re-introduced Sakinaw Sockeye Salmon are not considered wild under the Wild Salmon Policy, they are included in the definition of a wildlife species under SARA and therefore included in the Sakinaw Sockeye Salmon population for the purpose of this Recovery Potential Assessment (RPA).
- Numbers of mature Sakinaw Sockeye Salmon spawners varied from 750 to 16,000 over the period from 1947 to 1987 with no apparent trend, after which escapements declined drastically until 2006 when 0 or 1 adult returned to the lake each year from 2006 to 2009. Given that the generation time for Sockeye Salmon is four years, the Sakinaw Sockeye Salmon population was extirpated in the wild. Sockeye Salmon fry from hatchery releases began returning to Sakinaw Lake as adults in 2009.
- Sakinaw Sockeye Salmon marine survival during recent (2005-2016) years averages 0.23% for hatchery and 0.49% for natural origin Sockeye. Current marine survival rates are not sufficient to sustain the population; therefore continued hatchery supplementation is required to prevent another extirpation event until survival in the marine environment improves.
- Sakinaw Sockeye Salmon require different habitats at varying stages of their life cycle. While available spawning habitat is critical to the survival of Sakinaw Sockeye Salmon, it is not currently limiting Sakinaw Sockeye Salmon.
- Pollution, habitat degradation, and fishing were identified as the three main anthropogenic threats to Sakinaw Sockeye Salmon. Predation, competition, parasitism, and changing ocean conditions were identified as the limiting factors with the highest population level risk.
- Under current marine conditions, the survival of Sakinaw Sockeye Salmon requires human intervention through hatchery supplementation; without the enhancement program the population will likely go extinct.
- Although spawning and rearing habitat is currently not limiting Sakinaw Sockeye Salmon productivity, every measure should be taken to protect and to maintain the quality and quantity of Sakinaw Sockeye Salmon spawning and rearing habitat.
- Given the high early life history stage mortality and the extremely low marine survival of Sakinaw Sockeye Salmon, minimal allowable harm should be permitted at this time, and be reduced below current levels of harm to the 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 a number of 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.

Sakinaw Lake Sockeye Salmon (*Oncorhynchus nerka*) is the Designatable Unit of anadromous Sockeye Salmon that spawns in Sakinaw Lake. Throughout this report it will be referred to as Sakinaw Sockeye Salmon. This population was assessed as a Designatable Unit under the COSEWIC guidelines for recognizing Designatable Units because it is genetically distinct and reproductively isolated from other populations of Sockeye Salmon. Sakinaw Sockeye Salmon is anadromous, spawning and rearing in Sakinaw Lake, before migrating to the North Pacific Ocean, where they share migration corridors and foraging habitat with other Sockeye populations. They return to Sakinaw Lake at the end of their lifecycle to spawn. Sakinaw Sockeye Salmon have high cultural importance to the Shíshálh Nation (Sechelt First Nation).

Sakinaw Sockeye Salmon was first assessed by COSEWIC in 2002 as an emergency assessment and recommended as Endangered. The status was re-examined and confirmed in May 2003. The status was re-examined in another emergency reassessment and was confirmed in April 2006. As per section 24 of SARA, COSEWIC reviewed the classification of Sakinaw Sockeye Salmon in April 2016. The status of Sakinaw Sockeye Salmon was confirmed as Endangered (COSEWIC 2016). The following reason for designation was provided: "This population experienced a very large decline in the 1980s and 1990s because of low ocean survival and over-fishing. Brood stock from Sakinaw Lake are maintained in a captive-breeding program that produced fry and smolts released into the lake beginning in 2000. Despite these introductions, almost no adults returned to the lake in 2006-2009. Smolts from the captive-breeding program continued to be introduced and adults returned to the lake in 2010 through 2014. Some of these fish spawned successfully on historical spawning beaches, demonstrating that the program was having some success in re-establishing the population. However, the number of wild-hatched fish is very small. Threats from development around the lake, low ocean survival, and the fishery continue."

It is important to note that Sakinaw Sockeye Salmon are now all descendants of re-introduced fish from the captive breeding program.

Following the previous emergency assessments of Sakinaw Sockeye Salmon, the Governor in Council decided not to add Sakinaw Sockeye Salmon to the List of Wildlife Species at Risk set out in Schedule 1 of SARA. Although Sakinaw Sockeye Salmon was not listed, a recovery team was engaged to establish recovery goals and actions for Sakinaw Sockeye Salmon. An immediate recovery goal was to stop the decline of the Sakinaw Lake Sockeye Salmon population and re-establish a self-sustaining, naturally spawning population, ensuring the preservation of the unique biological characteristics of this population. An enhancement program was initiated in 2001 followed by a captive brood program to release fry into the lake with the goal of increasing the number of smolts migrating into the ocean.

In support of a new listing recommendation for Sakinaw Sockeye Salmon by the Minister of Fisheries and Oceans Canada, DFO Science has been asked to undertake a RPA, based on the national RPA Guidance (DFO 2014a). The advice in the RPA may be used to inform both scientific and socio-economic aspects of the listing decision, development of a recovery strategy and action plan, and to support decision making with regards to the issuance of permits or agreements, and the formulation of exemptions and related conditions, as per sections 73, 74, 75, 77, 78 and 83(4) of SARA. It may also be used to prepare for the reporting requirements of SARA section 55.

Sakinaw Lake

Sakinaw Lake drains into ocean via Sakinaw Creek (Figure 1). The lake outlet was periodically partially, or completely, blocked by dams built for logging purposes and water storage between 1911 and the 1930s. This likely reduced the access for migrating Sakinaw Sockeye Salmon; however, based on historic escapement counts periodic restrictions in access does not appear to have had a negative effect on the population. Escapement is the number of mature salmon that pass through (or escape) fisheries and return to fresh water to spawn. As part of logging activities near Sakinaw Lake during the first half of the 20th century, the lake was used as a log dump, millpond, and booming ground. A permanent dam and fishway were constructed on the outlet in 1952 by DFO to facilitate fish passage and reduce lake level fluctuation; lake levels have since been regulated to store water for the Sakinaw Sockeye Salmon migration. No staff were assigned to operate the dam and fishway from 1990-1999. When staff was reassigned to operate the dam and fishway in 1999, a beaver dam was completely blocking the fishway. Recently, DFO has undertaken restoration efforts to enhance spawning habitat at known spawning beaches.

Wild Salmon versus SARA Wildlife Species

Terminology used throughout this document in, and commonly used for both SARA and the Wild Salmon Policy, are defined and compared here to ensure clarity.

The WSP considers a salmon “wild” if it has spent its entire life cycle in the wild and originated from parents that were also produced by natural spawning fish and continuously lived in the wild. The WSP further defines a Conservation Unit (CU) as a group of wild salmon sufficiently isolated from other groups that, if extirpated, is very unlikely to recolonize naturally within an acceptable timeframe.

SARA defines a wildlife species as a species, subspecies, variety or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is native to Canada; or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years. The SARA wildlife species definition recognizes that conservation of biological diversity requires protection for taxonomic entities below the species level (i.e. Designatable Units or DUs), and gives COSEWIC a mandate to assess those entities when warranted. DUs should be discrete and evolutionarily significant units of the taxonomic species, where “significant” means that the unit is important to the evolutionary legacy of the species as a whole and if lost would likely not be replaced through natural dispersion. DUs and CUs may not be the same for salmon populations. However, for Sakinaw Sockeye Salmon, the boundaries for the CU defined under the WSP and the DU as defined by COSEWIC are the same.

According to some legal interpretations, the term “wild by nature” in the SARA definition of a wildlife species might include captive individuals with recent wild ancestors. This is the largest difference between how the WSP and SARA define a Sakinaw Sockeye Salmon. As per the COSEWIC manipulated populations guidelines, COSEWIC includes all intra-limital reintroductions as part of the wildlife species being assessed. Therefore, although the captive bred and re-introduced Sakinaw Sockeye Salmon are not considered wild under the WSP, they are included in the definition of a wildlife species under SARA and therefore included in the Sakinaw Sockeye Salmon population for the purpose of this RPA.

Biology, Abundance, Distribution and Life History Parameters

Biology

Reproduction

Sakinaw Sockeye Salmon are anadromous. They spawn along the shoreline of the lake where there are sources of upwelling groundwater. Most Sakinaw Sockeye Salmon mature after four years, after spending two years rearing in the lake and two years at sea before returning to Sakinaw Lake to spawn. Small proportions of Sakinaw Sockeye Salmon mature at three (3%) and five (10%) years of age.

Spawning occurs predominantly between mid-November and mid-December, but can occur as late as January. Females build redds (spawning nests) in gravel substrate and bury the eggs immediately after male fertilization for incubation. Incubation time can vary from as little as 50 days up to five months, depending on temperature. Alevin emerge from the hatched eggs and will spend three to five weeks in the gravel. Free-swimming fry (25 to 32 mm in length) emerge from the gravel in early May and move to well-lit, surface waters.

By March of the following year the juveniles move out of the lake as smolts via the creek to the Strait of Georgia, moving quickly into deeper water. The smolt migration is finished in June (Figure 2). The smolts migrate north through Johnstone Strait to the North Pacific Ocean.

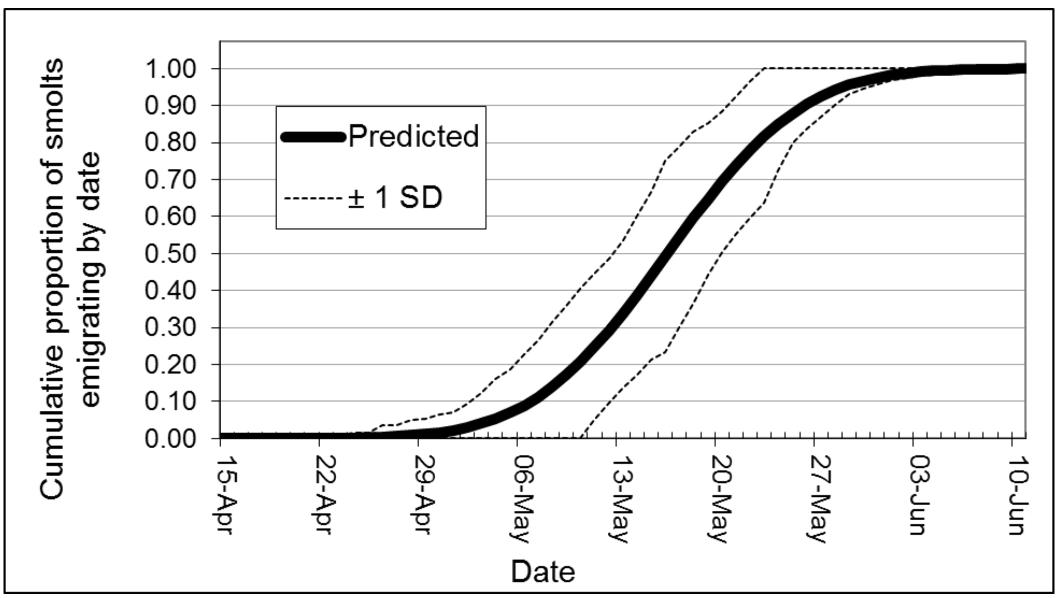

Figure 2. Sakinaw Sockeye Salmon smolt average run timing.

Feeding and Diet

After fry emerge from the gravel in early May, they move near the lake shoreline in the littoral zone to visually feed and then shift with age to deeper waters. As fry and smolts, Sakinaw Sockeye Salmon feed primarily on copepods (*Cyclops, Epischura,* and *Diaptomus spp.*), cladocerans (*Bosmia, Daphnia* and *Diaphanosoma spp.*), insect larvae and small fishes. As adults in the North Pacific, their diet shifts to euphausids, amphipods, copepods and young fishes.

Length and Weight

Sakinaw Sockeye Salmon smolts are large relative to other populations of Sockeye Salmon, but adults are relatively small. Larger smolts leave the lake during the early part of the out-migration, with smaller smolts leaving the lake towards the end. The mean smolt size from 1994 and 1997 ranged from 122.4 mm to 139.2 mm. Smolt weight data over this same time period ranged from 20.9 g to 28.3 g.

Natural and hatchery smolts measured at the Sakinaw Creek dam from 2003 to 2016 had an average fork length of 128.0 mm (±13.6 mm SD) and 126.9 mm (±18.8 mm SD), respectively. Average length of spawners collected in 2001 for brood stock was 445 mm (10 fish); 468 mm for five males, and 428 mm for five females. Sakinaw Sockeye Salmon passing through the fishway from 1957 to 1972 ranged in weight from 1.14 to 2.95 kg.

Distribution

Sakinaw Sockeye Salmon spawn and rear in Sakinaw Lake. When the fry emerge from the spawning beach gravel they generally move to deeper waters with age.

The majority of out-migrating (leaving Sakinaw Lake) smolts move north through Johnstone Strait to forage in the North Pacific Ocean with other Sockeye Salmon populations. During their first year at sea, Sockeye Salmon from British Columbia have been caught along the Alaska Peninsula during summer and fall, and near the Aleutian Islands during winter. Generally, Canadian Sockeye Salmon remain south of the Aleutian Islands and move northward during the summer and south during the winter.

During their return migration, Sakinaw Sockeye Salmon have been caught in the north end of the Strait of Georgia, Johnstone Strait, Juan de Fuca Strait, the South Gulf Islands and Puget Sound. The majority of the fish return by the north end of Vancouver Island and pass through Johnstone Strait. Between June and September, returning adults hold off the mouth of Sakinaw Creek for suitable high tides and darkness to access the creek and enter Sakinaw Lake. The peak return migration occurs at the end of July (Figure 3). Adult spawners hold in the lake for up to four months before spawning.

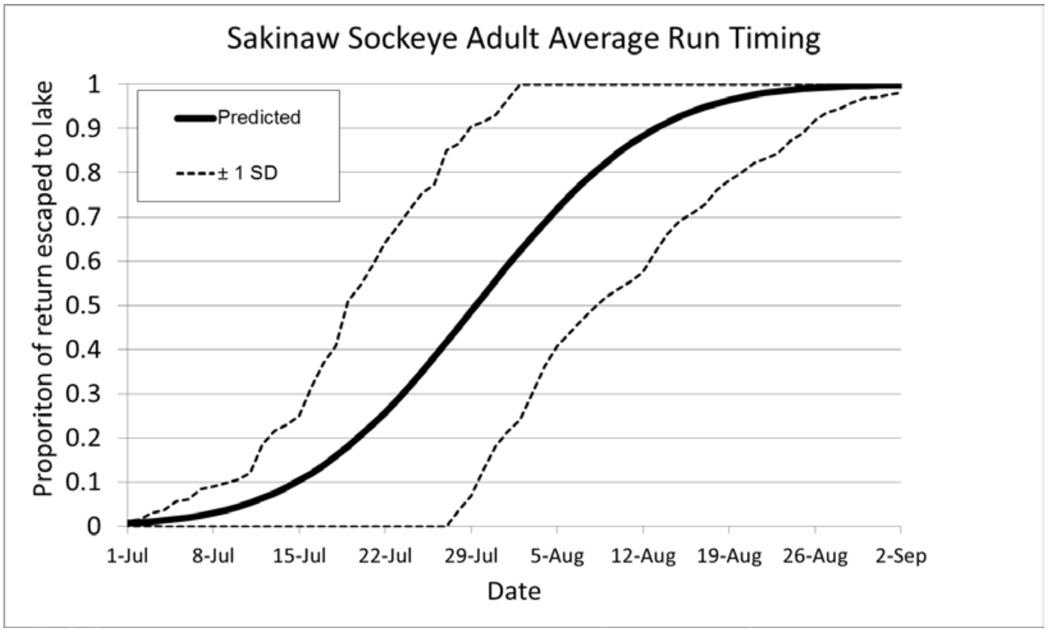

Figure 3. Sakinaw Sockeye Salmon adult average run timing.

Historically, there are five known spawning beaches in Sakinaw Lake, three in the upper basin (Sharon's, Haskins and Ruby) and two in the lower basin (Prospectors and Kokomo) of the lake. Since the 1990s, spawning only occurs at the upper basin beaches, and 2001 surveys indicated that Ruby had very limited use. Spawning occurs mainly near upwelling groundwater in underwater valleys associated with creeks, with the creeks inlets shifting along the beaches over time. The remaining beaches appeared to be of poor quality for spawning due to being overgrown with vegetation.

Abundance and Trends

Numbers of mature Sakinaw Sockeye Salmon spawners varied from 750 to 16,000 over the period from 1947 to 1987 with no apparent trend (Figure 4). After 1987, escapements declined drastically until 2006 when 0 or 1 adult returned to the lake each year from 2006 to 2009. Given that the generation time for Sockeye Salmon is four years, the Sakinaw Sockeye Salmon population was extirpated in the wild. A captive broodstock program was initiated during the collapse of the population to supplement the declining returns. Wild spawners (n=84) were used to establish this captive population from 2002 to 2005. Hatchery fry are released annually into the upper and/or lower basin of Sakinaw Lake, with subsequent smolt enumeration and adult return counts. The entire Sakinaw Sockeye Salmon population are now descendants from the captive population. Sockeye Salmon fry from the hatchery releases began returning to Sakinaw Lake as adults in 2009 (1 adult counted), followed by 29 spawners counted at the fishway in 2010. Between 2011 and 2016, an annual average of 328 (range 114 to 555) captive bred adult fish returned to the lake. Some of these fish were observed spawning on historical beaches. Hatchery adults that returned and spawned in 2011 produced natural origin spawners in 2015. During 2015 and 2016 an average of 130 natural adult fish returned to the lake.

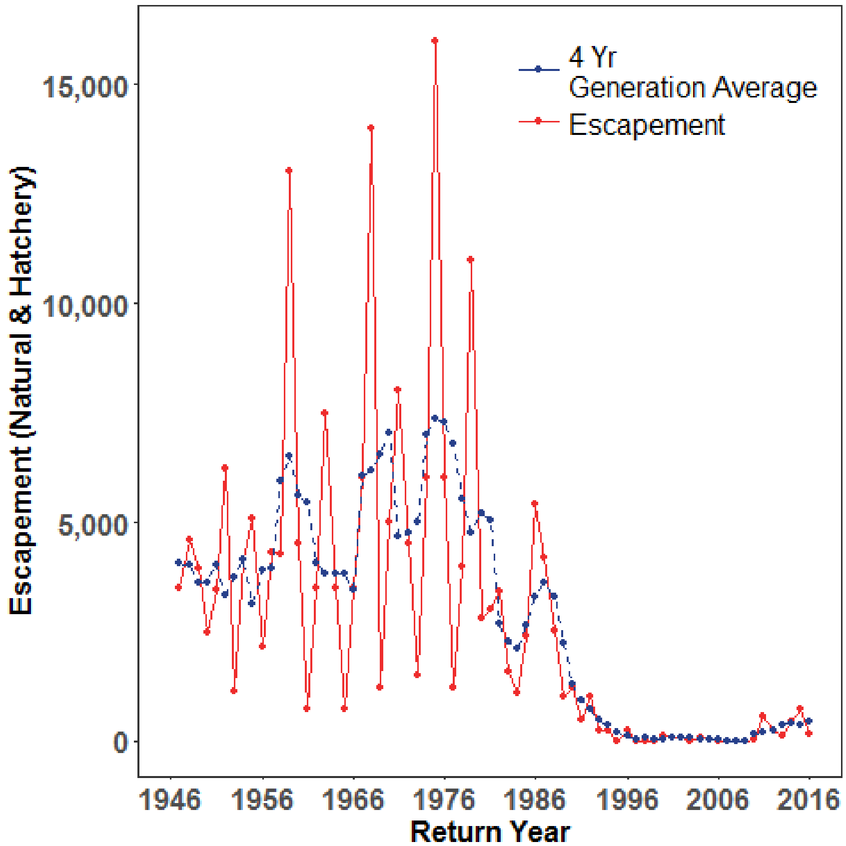

Figure 4. Sakinaw Sockeye Salmon escapement from 1947 to 2016. The counts from 1953 to 1994 are from BC-16 data. Insufficient data exists for 1995, 1997, and 1998 so they were not included. Data for 1999 to 2001 are based on dive surveys at spawning beaches which are biased low compared to fishway counts due to in-lake mortality (estimated at up to 10% bias). Counts from 2003 to 2016 are from a digital video system set up in the fishway.

Hatchery fry from the captive brood program continue to be produced to supplement natural recruitment while escapement remains low. Hatchery fry released between 2001 and 2016 varied from 0 to 1,373,822 fry. Smolts counted out-migrating from the lake between 2003 and 2015 range from 13 smolts in 2005 to 252,535 smolts in 2011. Hatchery-released fish are marked with an adipose fin clip prior to release to allow identification of smolts and returned adults as being of hatchery or natural spawner origin.

Life History Parameters

Growth and Natural Mortality

There are no natural egg to fry survival data for Sakinaw Sockeye Salmon. In 2013, DFO examined egg to fry survival (from eyed-egg stage) in boxes buried in gravel on four spawning beaches in Sakinaw Lake. Average egg to fry survival was 78%, ranging from 0% to 100%. The high average survival is likely due to the protected conditions within the boxes, which would protect the eggs from predation and therefore is not representative of the true conditions.

Average hatchery fry to smolt survival in Sakinaw Lake is 13.8% (range 1.4% to 32.2%). The survival rate of hatchery fry has no relationship with the number of fry released; however, the number of fry released has a positive relationship with the number of hatchery smolts counted at the dam in Sakinaw Creek. There is no data on the survival rate of wild fry to smolt for Sakinaw Sockeye Salmon.

Sakinaw Sockeye Salmon marine survival during recent (2005-2016) years averages 0.23% for hatchery and 0.49% for natural origin Sockeye (Figure 5). Current marine survival rates are not sufficient to sustain the population; therefore continued hatchery supplementation is required to prevent another extirpation event until survival in the marine environment improves.

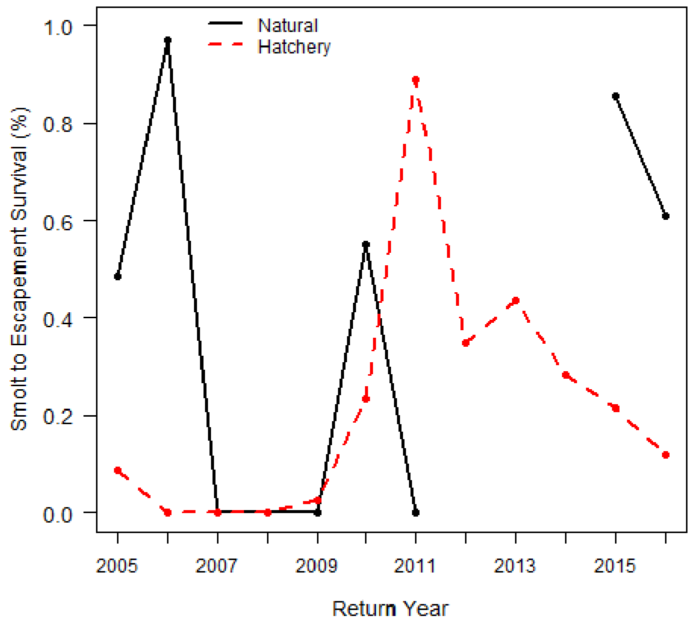

Figure 5. Marine survival (smolt to escapement) of natural and hatchery Sakinaw Sockeye Salmon from 2005 to 2015 (return year).

Adult spawners hold in the lake for up to four months before spawning. In–lake mortality during the holding period is unknown. However, in years with low returns, when thorough dive counts were conducted (2004 and 2005), the number of fish counted at the fishway and during later dive surveys suggest that pre-spawning mortality is low (≤10%).

ASSESSMENT

Habitat and Residence Requirements

Similar to other salmon, Sakinaw Sockeye Salmon require different habitats at varying stages of their life cycle.

Spawning Habitat

Sakinaw Sockeye Salmon adults spawn in gravel on beaches near creeks or other sources of groundwater.

In 1979, the amount of Sockeye Salmon spawning habitat in Sakinaw Lake was visually estimated to be 6,000 m^2. In 2015, there was approximately 3,000 m^2 of suitable spawning habitat. This more recent study used a GPS unit and is higher quality data than the 1979 study;

therefore, it is hard to determine if the quantity of habitat has actually decreased since 1979. The quality of habitat within the 3,000 m^2 varies due to the presence of woody debris, slope and substrate type. Based on the recent estimate of spawning area available at Sakinaw Lake, Sockeye redd size (0.94 m^2) and the area required to spawn (2.5 to 3 m^2), there is space for 1,000 to 1,200 females to spawn simultaneously. While available spawning habitat is critical to the survival of Sakinaw Sockeye Salmon, it is not currently limiting Sakinaw Sockeye Salmon.

Freshwater Rearing Habitat

Sakinaw Lake has two distinct basins and covers an area of 6.9 km^2. The lower basin is the largest with a maximum depth of 140 m and a mean depth 43 m. The upper basin is shallow with a maximum depth of 40 m. Sakinaw Lake is unusual compared to most other lakes in that it has layers that do not mix (i.e., meromictic), with a 30 m freshwater layer overlying an anoxic, salt water layer in the lower basin. The lake's upper basin is not meromictic.

The upper 7 m (thermocline) of the water column becomes very warm (23 °C) during the summer and decreases to 5°C at 40 m depth. From 10 to 20 m depth the temperature is between 6 and 13°C. Juvenile Sockeye Salmon prefer temperatures of 11°C to 15°C, and they will move to avoid temperatures above 17°C. Therefore, the amount of lake rearing volume available to juvenile Sockeye might be smaller during warmer periods.

Sakinaw Lake is a very productive relative to most other coastal BC lakes, but less productive than most Fraser River system lakes. Further data collection and analysis is needed to determine the carrying capacity of Sakinaw Lake.

Sakinaw Creek and Fishway

Adult Sakinaw Sockeye Salmon only spawn in Sakinaw Lake, therefore they require the lake to survive, including passage in and out of the lake via Sakinaw Creek during migration. Sakinaw Creek has been recommended as a component of critical habitat for Sakinaw Sockeye Salmon.

Adult Sakinaw Sockeye Salmon can only migrate up the creek during high tides and predominantly only do this during the night. Otherwise, water levels within the creek below the fishway are too low for adults to swim up the creek. The fishway can also act as a barrier if it is not maintained and the doorway is closed which blocks adult migration, although it is believed that some adults have jumped over the weir in the past.

Marine Rearing Habitat

Marine habitat requirements for Sakinaw Sockeye Salmon are assumed to be similar to other lake-type Sockeye Salmon and include unrestricted ocean corridors and feeding grounds of appropriate temperature and productivity. They are typically found in waters between 3.3°C and 13.3°C and shallower than 15 m depth. The majority of Johnstone Strait, Strait of Georgia and Juan de Fuca Strait have the nearshore habitat properties required by Sakinaw Sockeye Salmon smolts and adults. Although climate-driven natural variability in ocean productivity will influence the survival of Sakinaw Sockeye Salmon, management of habitat in marine areas other than the migratory corridor is unlikely to be possible.

Residence

Under SARA, a residence is defined as a dwelling-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 (SARA section 2.1). Following DFO’s Guidelines for the Identification of Residence and Preparation of a Residence Statement for an Aquatic Species at Risk (DFO 2015), redds most closely match the criteria for a residence because they are constructed. Redds have a structural form and function of a nest, the female has invested energy in its creation, redds are essential for successful incubation and hatching of the eggs, and redds can contain hundreds to a few thousand eggs from a female Salmon. Redds located at the spawning beaches in Sakinaw Lake could be considered residences.

Threats and Limiting Factors to Survival and Recovery

To assess and prioritize the threats and limiting factors to the survival and recovery of Sakinaw Sockeye Salmon a threats and limiting factors analysis workshop was held (December 15-16, 2016, Nanaimo, BC). An expert panel including: DFO research scientists; salmon stock assessment biologists; Salmon Enhancement Program managers and hatchery staff; Fisheries Management; representatives from Sechelt First Nation; Sunshine Coast biologists familiar with Sakinaw Sockeye Salmon; and a representative from the Sakinaw Lake Community Association, met during this workshop and discussed the various threats, limiting factors and activities that affect the Sakinaw Sockeye Salmon population and habitat. A summary of the workshop is provided in Research Document from this process. Scores from the workshop were later adapted to DFO's (2014b) *Guidance on Assessing Threats, Ecological Risk and Ecological Impacts for Species at Risk* scoring matrices and threats that were identified in the COSEWIC assessment were also included.

Threats are defined as anthropogenic activities that negatively affect the productivity of Sakinaw Sockeye Salmon. Limiting factors are defined as natural (i.e. abiotic or biotic) factors that negatively affect their productivity.

For completeness and due to the magnitude that limiting factors affect the survival and recovery of Sakinaw Sockeye Salmon, the potential ecological impacts of limiting factors are also discussed below.

Threats

Pollution

Elevated mortality or sub-lethal effects due to aquatic pollutants was determined to be a medium population-level risk with low confidence. Activities within the Georgia Basin, such as shipping, farming and industry contribute pollutants to the marine environment as a result of collisions, spills, loss of ships at sea, coastal runoff and direct water discharge. The effects of these activities are believed to be very low within Sakinaw Lake but they likely have a larger effect in the Georgia Basin. The release of hydrocarbons in Johnstone Strait and the Strait of Georgia could negatively affect the migratory habitat (marine rearing habitat) of smolts and adult Sakinaw Sockeye Salmon. There is potential for shipping of oil and gas to increase from the Vancouver area in the future, which will increase the probability that a spill will occur. This threat will have the greatest effect if the spill overlaps spatially and temporally with fish migration routes.

Overall, pollution is currently believed to have a medium population-level threat risk.

Habitat Degradation

Habitat degradation affects terminal migration and spawning, freshwater incubation, and freshwater rearing.

Historically, Sakinaw Lake was used as a log dump, millpond and booming ground as part of logging activities in the area. The majority of this impact occurred in the 1950s and 1960s; however, Sakinaw Sockeye Salmon productivity remained relatively high. Forestry is ongoing within the Sakinaw drainage. Impacts from recent forestry are considered to be negligible.

Upland development and other shoreline development that affects creek inflow volume and routes, and groundwater supply will reduce spawning habitat quality. Upland development also has the potential to cause erosion of stream banks and increase the transport of fine sediment and debris into the lake[1]. Therefore, shoreline and upland development have the potential to decrease the quality and stability of spawning gravel which would decrease egg and alevin survival. The removal of riparian vegetation may contribute to lake warming, which may increase adult and egg mortality. However, spawning and holding depth is believed to be deep enough to not be affected by relatively small increases in water temperature. There has been no development near any spawning beaches since the 1960s.

Historically, Sockeye spawning occurred at 5 beaches in Sakinaw Lake (Sharon's, Haskin's, Ruby, Kokomo and Prospector's). Currently, spawning only occurs at the four sub-beaches at Sharon's and at Haskin's. DFO has undertaken recent restoration efforts to enhance spawning habitat at known beaches (Sharon's and Haskin's), including clearing fallen trees, woody debris, large rocks and accumulated sediment and loosening of compacted gravel from marked redds.

Spawning habitat has been affected by maintaining lake levels with the dam. The lake outlet has been partially or completely blocked since the early 1900s by dams built for log and water storage. A permanent dam and fishway were constructed by DFO on the outlet in 1952. Since then, lake levels have been regulated to store water for the Sockeye migration and indirectly the developing recreational and cottage community. Maintaining lake levels within a relatively stable and unnatural range has led to increased vegetation, fine sediment and accumulation of woody debris on the spawning beaches, particularly at Ruby and Prospectors beaches. Restoration work at spawning beaches, since the sockeye population declined, has improved the extent of spawning habitat.

Overall, freshwater habitat degradation is currently believed to have a low population-level threat risk.

Fishing

Sakinaw Sockeye Salmon migrate back to Sakinaw Lake through Johnstone Strait. They share this migration corridor with other Sockeye Salmon populations including those returning to lakes in the vicinity of Johnstone Strait and the northern diversion component of Sockeye returning to the Fraser River. The northern diversion refers to the proportion of returning Fraser Sockeye migrating through Johnstone rather than Juan de Fuca Strait.

Sakinaw Sockeye Salmon have been killed both as directed catch in terminal fisheries and as incidental catch in mixed-stock fisheries targeting larger populations of Sockeye and Pink Salmon (*O. gorbuscha*). Various estimates of Sakinaw Sockeye Salmon exploitation rate have been made. Average estimates for years with available data are: 41% between 1970 and 1982, 27% between 1987 and 1990, 47% between 1993 and 1994, and 15% between 1997 and 2005. An average of two estimates for 2010 is 18%. The average exploitation rate from 2011 to 2015 was 5%.

The number of Sakinaw Sockeye Salmon caught by Indigenous fishers in food, social and ceremonial (FSC) fisheries is unknown because there is no sampling program (e.g. DNA sampling) for fish caught in these fisheries.

[1] Ramshaw, B., Luedke, W, 2018. Recovery Potential Assessment for the Sakinaw Lake Sockeye Salmon (Onchorhynchus nerka) (2017). DFO Can. Sci. Advis. Sec. Res. Doc. 2018/nnn. vi + xx p. unpublished data.

The current estimated exploitation rate of 5% resulted in fishing being scored as a low population-level threat risk.

Limiting Factors

Predation and Competition

Adult Sakinaw Sockeye Salmon face a high level of predation during their terminal migration and spawning. Among potential mammalian predators are River Otters, seals, sea lions, Mink, bears, and Killer Whales. River Otters were identified as the greatest predation concern overall. They feed on adult Sockeye in Sakinaw Creek and fishway.

Predation is also thought to be high on eggs and alevins during freshwater incubation. Fish predators of Sockeye eggs and alevin include Cutthroat Trout, juvenile Coho and Chinook Salmon, Prickly Sculpin and Peamouth Chub. Depensatory mortality is likely occurring as the number of spawners has drastically decreased and the number of spawning beaches has also decreased, thus concentrating predators at two spawning beaches.

Predation on smolts was also scored as a high population-level risk. Seals and sea lions are seen in the estuary and believed to be increasing in abundance in the area which would increase mortality for smolts and adults

Competition with other species was scored as a high current and future biological risk. Cutthroat Trout, Coho Salmon, Kokanee and stickleback are present in Sakinaw Lake. These are all competitors of Sakinaw Sockeye Salmon fry and smolts, but the degree to which this limits Sakinaw Sockeye Salmon productivity is unknown. Competition at sea between Pink Salmon and Sockeye Salmon is believed to have a negative effect on Sockeye Salmon recruitment. During their first year at sea, early marine scale growth of two Fraser river Sockeye Salmon populations has been shown to be negatively correlated with regional abundances of juvenile Pink Salmon.

Parasitism

Parasites and pathogens are characterized as a medium population-level risk. On average, 3.5% of smolts counted at the dam have a lamprey scar. In most years, less than 15% of out-migrating smolts have had copepods on their gills. Although this rate of parasitism is very low, it is possible that a significant portion of those individuals that are parasitized do not survive to outward migration.

Changing Ocean Conditions

Low production regimes occurring in the northeast Pacific Ocean can negatively affect Sakinaw Sockeye Salmon. Marine survival is believed to be the predominant limiting factor in the recovery of Sakinaw Sockeye Salmon. The average smolt to adult survival rate is 0.23% for hatchery fish and 0.49% for wild fish, which is insufficient to sustain the population without hatchery supplementation. With all other factors being equal, smolt to adult survival needs to be at least 5.25% to achieve a return per spawner ratio greater than 1. The only early marine survival data available is from 2004 and 2006, where 18% and 10%, respectively, of tagged smolts successfully migrated from Sakinaw Lake to the north end of Vancouver Island.

Wood et al. (2012) found that Sakinaw Sockeye Salmon smolt migration route and timing through the Strait of Georgia was similar to that reported for upper Fraser River Sockeye populations. Due to the unexpectedly high survival of tagged fish that did not leave the Strait of Georgia, the authors concluded that factors outside the Strait of Georgia must be causing the extremely low marine survival of Sakinaw smolts that migrate to the north Pacific Ocean.

Hatchery Considerations

Hatchery practices are an important consideration in the survival of Sakinaw Sockeye Salmon. Improved hatchery practices can increase the survival of the released Sakinaw Sockeye Salmon. The captive breeding program was the only source of Sakinaw Sockeye Salmon with which to re-establish a natural population once the original population was extirpated from the lake for an entire four year cycle. However, there are challenges associated with the hatchery program. There is high mortality of hatchery fish from the fry to smolt stage, and high mortality of hatchery fish from the smolt to adult stage due to domestication and lowered fitness. Despite those challenges, the hatchery program has been essential to the maintenance and restoration of the natural Sakinaw Sockeye Salmon population.

Sakinaw Sockeye Salmon Threats and Limiting Factor Assessment

Threats and limiting factors for Sakinaw Sockeye Salmon discussed above were prioritized in a table following the requirements laid out by DFO (DFO 2014b) (Tables 1 and 2). The DU-level threat and limiting factor risk is calculated using rankings for level of impact and likelihood of occurrence and plotting them in the Threat Risk Matrix to derive an overall threat or limiting factor risk.

Table 1. Threats to the survival and recovery of Sakinaw Sockeye Salmon. Threats are ranked based on their current biological risk score.

Life History Stage	Threat	Likelihood of Occurrence	Level of Impact	Causal Certainty	Population -Level Risk	Threat Occurrence	Threat Frequency	Threat Extent
Marine Migration and Rearing	Pollution: Elevated mortality or sub-lethal effects due to aquatic pollutants	Likely	Medium	Low	Medium (4)	Historical/ Current/ Anticipatory	Recurrent	Extensive
Terminal Migration and Spawning, Freshwater Incubation and Freshwater Rearing	Habitat degradation: Habitat integrity degraded sufficiently to negatively impact smolt staging, rearing or early seaward migration requirements	Known	Low	High	Low (2)	Historical/ Current/ Anticipatory	Continuous	Extensive
Terminal Migration and Spawning	Fishing: Increased adult mortality due to terminal fisheries	Known	Low	Very High	Low (1)	Historical/ Current/ Anticipatory	Recurrent	Restricted

Table 2. Limiting factors to the survival and recovery of Sakinaw Sockeye Salmon. Only limiting factors that were scored as "medium" or higher for Population-Level Risk are presented. Limiting factors are ranked based on their Population-Level Risk score.

Life History Stage	Limiting Factor	Likelihood of Occurrence	Level of Impact	Causal Certainty	Population-Level Risk	Limiting Factor Occurrence	Limiting Factor Frequency	Limiting Factor Extent
Terminal Migration and Spawning	Large losses due to predation (LF1)	Known	Extreme	High	High (2)	Historical/ Current/ Anticipatory	Continuous	Extensive
Freshwater Incubation	Predation on eggs and alevins (by sculpins, Cutthroat Trout, Peamouth Chub, Coho, birds, etc.) (LF14)	Known	High	Low	High (4)	Historical/ Current/ Anticipatory	Continuous	Extensive
Marine Migration and Rearing	"Warm ocean" food webs favor below average smolt-to-adult survival and below average returns (LF32)	Known	Extreme	Medium	High (3)	Historical/ Current/ Anticipatory	Recurrent	Extensive
Marine Migration & Rearing	Competition exceeds historic reference range and is associated with density dependent growth or survival outcomes that are negative for Sakinaw Sockeye Salmon (LF29)	Likely	High	Low	High (4)	Current/ Anticipatory	Continuous	Extensive

Life History Stage	Limiting Factor	Likelihood of Occurrence	Level of Impact	Causal Certainty	Population-Level Risk	Limiting Factor Occurrence	Limiting Factor Frequency	Limiting Factor Extent
Marine Migration and Rearing	Predator abundance and assumed levels of predation on smolts and adults exceed reference range. State change is associated with reduced survival and well below average adult returns (LF33)	Known	Extreme	High	High (2)	Historical/ Current	Continuous	Extensive
Freshwater Rearing	High levels of competition or predation (from native or exotic spp.) reduce lake carrying capacity for wild fry-smolts (LF21)	Known	Medium	Low	Medium (4)	Current/ Anticipatory	Continuous	Extensive
Freshwater Rearing	High rates of parasitism reduce the lake carrying capacity for wild fry-smolts (LF22)	Known	Medium	Low	Medium (4)	Current/ Anticipatory	Continuous	Extensive
Freshwater Rearing	Variable food web structure (spp. changes) leads to sub-average carrying capacity for fry-smolts (LF18)	Likely	Medium	Low	Medium (4)	Current/ Anticipatory	Continuous	Extensive
Marine Migration and Rearing	Parasite or pathogen incidence & impacts on growth or survival expressed at epidemic levels associated with below average growth, survival and adult returns (LF35)	Likely	Medium	Low	Medium (4)	Historical/ Current/ Anticipatory	Continuous	Extensive

Survival and Recovery Thresholds

The terms “survival” and “recovery” are used frequently throughout the *Species at Risk Act* but are not defined within it. Survival and recovery are on a continuum of probability of persistence that ranges from the historical condition when human activity caused no effect to the lowest level where species survival is no longer possible.

As described in the Government of Canada’s (2016) *Draft Species at Risk Act Policies: Policy on Survival and Recovery*, “the competent minister(s) will consider that a species at risk has an acceptable chance for survival in Canada when it has surpassed the *survival threshold*.”

Under current marine conditions, the survival of Sakinaw Sockeye Salmon requires human intervention through hatchery supplementation. If current marine conditions change resulting in improved marine survival, the current brood stock and fish spawning in the wild could serve as a basis for recovery to occur. However, in the absence of the hatchery release program, the species would likely become extinct.

In order to meet the meet the minimum recovery threshold criteria, Sakinaw Sockeye Salmon would need to no longer be reliant on human intervention. As described below, this was determined to be an abundance that has a relatively low probability of extirpation (probability < 25%) over 100 years, which is 2,440 spawners.

Recovery targets are proposed below to contribute to recovery planning and provide supporting information for management decision making.

Recovery Targets and Timeframe of Recovery

Recovery Targets

The Sakinaw Sockeye Salmon Recovery Team proposed an overall goal in the 2005 conservation strategy to stop the decline of the Sakinaw Sockeye Salmon population and reestablish a self-sustaining naturally spawning population. Interim recovery goals were initially proposed with the following timelines and objectives:

- 2004–2007: increase the annual number of spawners (including those removed for hatchery bloodstock) to no fewer than 500;
- 2008–2011: increase the number of naturally produced spawners to no fewer than 500 annually, and;
- 2012–2017: ensure that by 2017, the mean population abundance in any four- year period exceeds 1000 naturally produced spawners, with no fewer than 500 naturally produced spawners in a year (Sakinaw Recovery Team 2005).

Due to the threats and limiting factors described above and very low marine survival, these targets have not been achieved. Since the initial abundance targets were proposed, extensive literature has been published which provided a basis for reviewing the existing targets. Updated interim stock state indicators and recovery targets are proposed (Table 3).

An interim stock state indicator for Sakinaw Sockeye Salmon of achieving continued growth in the generational average by increasing spawner abundance relative to the brood year (4 years prior) for at least 3 out of 4 consecutive years is proposed.

As an update to previous recovery targets, a new interim stock state indicator is recommended: increase the average number of naturally (i.e. not released from hatchery) produced spawners to no fewer than 500 over a four year period, with no fewer than 100 spawners in a given year. If this interim target was met, a further stock state indicator of increasing the mean number of natural spawners to no fewer than 1,000 in any four year period, with no fewer than 500 naturally produced spawners in any year is proposed.

Recovery targets based on benchmarks are also outlined. First, S_{gen} (2,440 spawners) is recommended, which was determined to be an abundance that has a relatively low probability of extirpation (probability < 25%) over 100 years, and with respect to Sakinaw Sockeye Salmon corresponds to the critical-cautious boundary in DFO's Fishery Decision-Making Framework Incorporating the Precautionary Approach. A second recovery target of 80% S_{msy} (4,470 spawners) is proposed as it differentiates between cautious and healthy zones.

A distribution target of maintaining spawning at the three spawning beaches that Sakinaw Sockeye Salmon have most recently used for spawning is proposed. This includes Sharon's, Haskins and Ruby beaches. The current area of spawning habitat is 3,000 m^2. This is enough area for 1,000 to 1,200 females to spawn simultaneously. To reach the higher recovery targets of 2,440 and 4,470 spawners (male and female), an additional 3,000 to 3,700 m^2 is needed for the former and 5,600 to 6,700 m^2 for the latter. Note that the whole population does not spawn simultaneously, thus the estimated spawning habitat required is a maximum.

Table 3. Proposed Sakinaw Sockeye Salmon stock state indicators and recovery targets.

Interim Stock State Indicator	Description
1) Population growth	Growth in the generational average by increasing natural spawner abundance relative to the brood year (4 years prior) for at least 3 out of 4 consecutive years after the recovery plan is implemented.
2) 500 natural spawners	An average of 500 annually over a four year period with no fewer than 100 fish.
3) 1,000 natural spawners	An average 1,000 annually over a four year period with no fewer than 500 fish. COSEWIC Criterion D1 and 2005 recovery target.
Recovery Target	**Description**
1) 2,440 natural spawners	S_{gen}. Achieve in any year.
2) 4,470 natural spawners	80% S_{msy}. Achieve in any year.
3) Spawning at Sharon's, Haskins and Ruby beaches	The three spawning beaches that have been used most recently. To reach a recovery target of 4,470 spawners it is likely that all five spawning beaches would be required to provide spawning habitat for all spawners.

The fate of Sakinaw Sockeye Salmon under current conditions (i.e. life history stage mortality rates, exploitation, etc.) was modeled. The current captive brood program (750 adult captive broodstock) was also used in the simulation. Sakinaw Sockeye Salmon had a 19% probability of achieving the population growth stock state indicator (1), and a 0% probability of reaching any of the abundance-based recovery targets. The probabilities are the number of years out of 100 years into the future that a target is achieved. This is averaged over 1000 trials. Extinction is the percentage of trials where extinction occurred.

A population viability analysis (PVA) was completed to model viability scenarios by varying current marine (smolt to spawner) and freshwater (fry to smolt) survival rates. Exploitation (5%) and per-spawn mortality (10%) rates remained constant. Marine survival rates were increased from 0.5% to 1%, 2%, 3%, 4%, 8% and 12% while freshwater survival was increased by 1.5 and 2 fold. Sakinaw Sockeye Salmon marine survival has not been observed as high or near 4% in over 15 years, and it is unknown if it will be this high in the future.

The probability of extinction was low for all scenarios due to the continued operation of the captive brood program. Increasing freshwater and marine survival increased the probability of increasing the population abundance relative to the previous generation; however the probabilities remained between 25% and 30% for both natural and wild spawners.

Increasing marine survival to 8% increased the probability of achieving stock state indicator 2 (500 spawners) to 76% (Figure 6). All scenarios for stock state indicator 2 reached a maximum at approximately 80% due to density dependence in smolt production as spawner and smolt data is only available for when the stock productivity was low.

Probabilities for achieving stock state indicator 3 (1000 spawners) were below 50% for all scenarios (Figure 7). Increasing marine survival to 12% increased the probability of reaching stock state indicator 3 to a maximum of approximately 45%. Increased freshwater survival for a given marine survival rate marginally increased the probability of achieving the target.

Probabilities for recovery targets 1 (2,440 spawners) and 2 (4,470 spawners) were 0% for all scenarios. Sakinaw Sockeye Salmon abundance has reached these abundances 32 and 16 times since 1947, respectively. However, under current conditions this has zero probability of occurring.

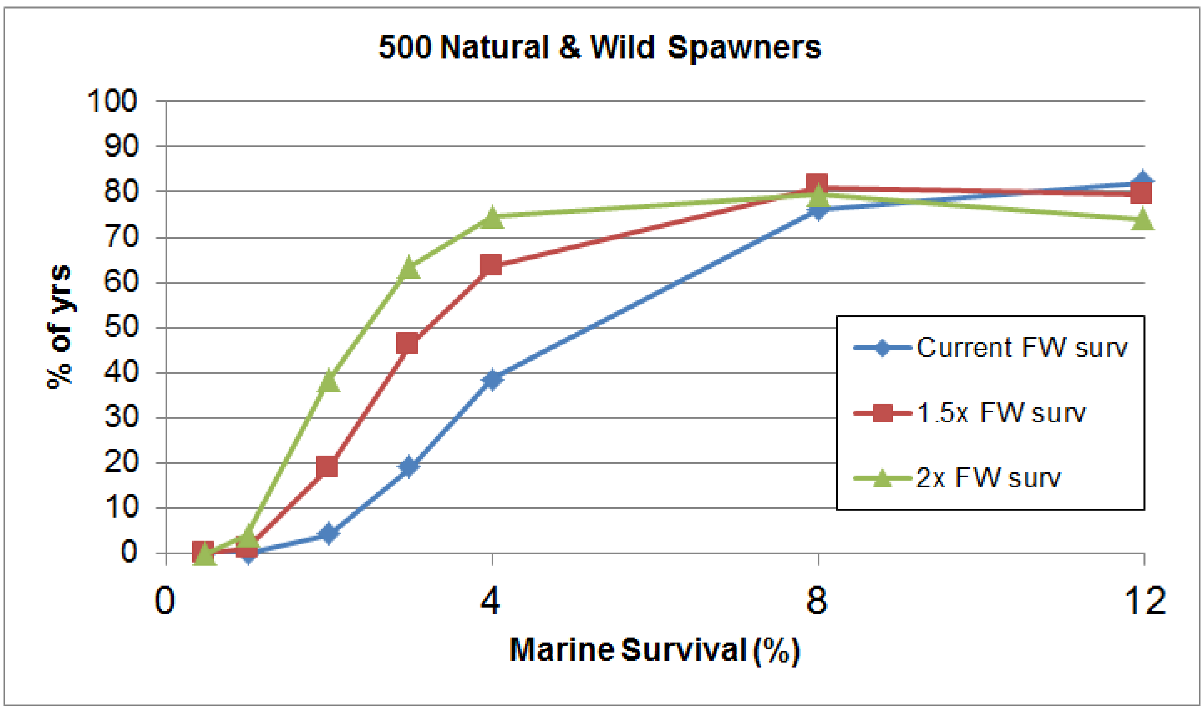

Figure 6. Percentage of years (probability) that the stock state indicator of 500 natural and wild spawners is met based on PVA model

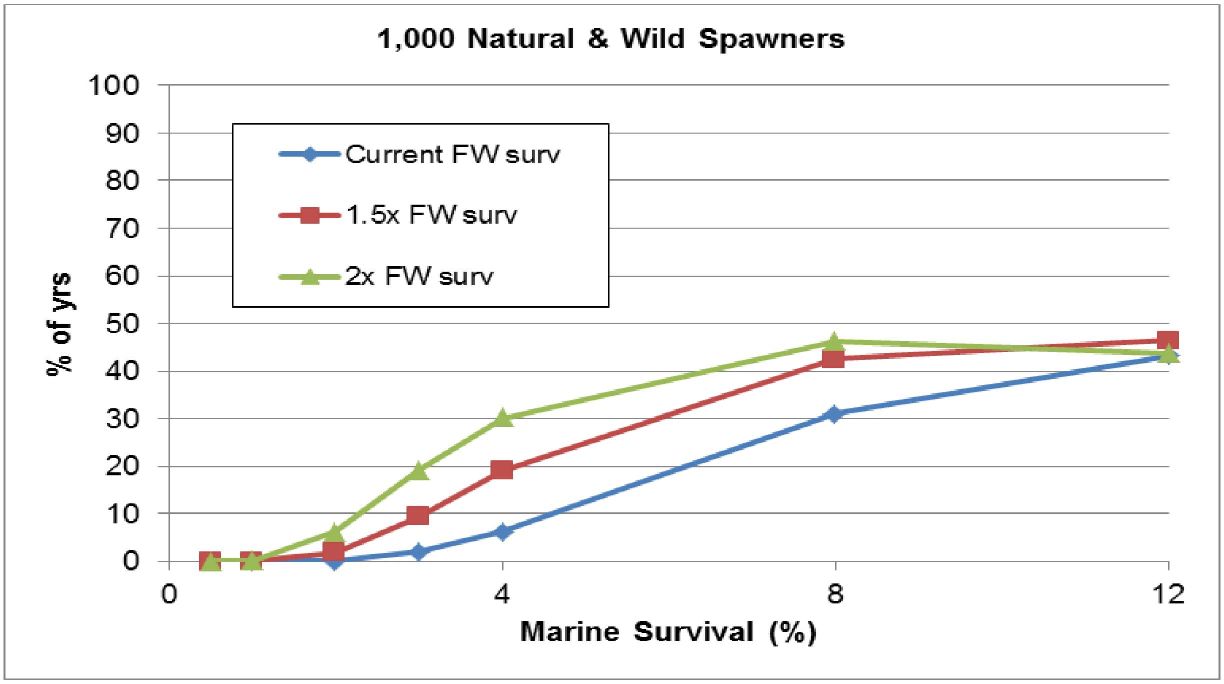

Figure 7. Percentage of years (probability) that the stock state indicator of 1000 natural and wild spawners is met based on PVA model

A deterministic life history model was also developed. With current wild fecundity (2,049); freshwater survival (19%), exploitation (5%) and pre-spawn mortality (10%) rates; a 7% marine survival rate is required to achieve >1 recruits per spawner and positive population growth. This model is strictly for wild fish, with a hypothetical starting population of 500 adults and does not include the captive brood program.

Mitigation Measures and Alternatives

Mitigation options and reasonable alternatives were proposed and discussed during the threats and limiting factors workshop in December 2016 and again during the RPA peer review in April 2017.

Threats

Pollution

1. Develop spill response plans that have adequate resources to quickly respond to a spill.

Habitat Degradation

1. Restrict development, forestry, and other industrial activities upslope of Sakinaw Sockeye Salmon spawning habitat to reduce sediment, slope stability and groundwater effects to the spawning beaches.
2. Restore natural fluctuation in lake levels to reduce nearshore benthic vegetation that is decreasing the availability of spawning habitat.

Fishing

1. Develop sampling program with First Nations to determine the number of Sakinaw Sockeye Salmon caught in food, social and ceremonial (FSC) fisheries, as it is currently unknown.

2. Continue fisheries management policies that restrict fishing in Johnstone Strait until the end of July when approximately 50% of the Sakinaw Sockeye Salmon have returned to Sakinaw Lake.

Limiting Factors

Competition and Predation

1. Staff present at the dam and fishway to continue to scare off predators during the return of adult Sockeye to Sakinaw Lake.
2. Predator exclusion cages could be implemented on the spawning beaches to protect the eggs and alevins, but more research is needed to see if this is a causal factor for the limited freshwater productivity of Sakinaw Sockeye Salmon.
3. A better understanding of potential predator and competitor (e.g. Cutthroat, Kokanee) dynamics is required to see if this is a causal factor for reduced fry to smolt survival. Possible mitigation includes the removal of competitors and predators through increased recreational fishing pressure or removing individuals from their spawning grounds through coordination with local stewardship groups.

Changing Ocean Conditions

1. Releasing more fry into the lake than is being done currently would increase the number of out-migrating smolts and returning adults. However, this does not directly mitigate the limiting factor of poor marine survival. This option would also have a significant increase in financial cost. Similarly, releasing hatchery fish as smolts may increase marine survival; however, this likely has an increased financial cost as well.

Hatchery Considerations

1. Maintaining already established captive breeding program measures to avoid inbreeding and incorporate diversity from all individuals.
2. Fry are transported in tanks by truck from Vancouver Island to the Sunshine Coast. Reducing the transportation time and decreasing the tank water temperature before release have been identified as two mitigation options. Transporting the fish from Rosewall hatchery to Sakinaw Lake via helicopter would reduce transport time and thus mortality. Refrigerating the transport tanks to keep the water temperature lower is another option that will likely decrease fry to smolt mortality.
3. A new site has been identified with a suitable well and surface water hatchery for a long-term program in the Pender Harbour area. This will allow fed, clipped fry to be released in mid-June to possibly duplicate the earlier Ouillet survival rates. Construction of a new hatchery at Pender Harbour will cost approximately $250,000 to build and $100,000 annually to operate.
4. Releasing fish over deep water away from the shoreline is also recommended as fry will have an easier route to access colder water.
5. Releasing fry in late summer or early fall when the water is cooler and the fry are larger will likely increase fry to smolt survival.

Allowable Harm

Currently, the factors that are preventing the recovery of Sakinaw Sockeye Salmon are not human induced, but rather are limiting factors, including high levels of predation, changing ocean conditions and other unknown causes of high at sea mortality. The Sakinaw Sockeye Salmon population is currently maintained by the release of fry into Sakinaw Lake from an enhancement program. Without the enhancement program, and with current life history stage survival rates and very low marine survival, anadromous Sakinaw Sockeye Salmon would likely become extinct.

Fisheries management plans implemented during the 1990s have been effective in reducing exploitation of Sakinaw Sockeye Salmon. The average exploitation rate for Sakinaw Sockeye Salmon from 2011 to 2015 was 5%. Model results indicated that further decreasing the exploitation rate to 0% would have little effect on recovery due to the small population size and low marine survival (0.5%). Therefore, maintaining the current 5% exploitation rate per year does not change the trajectory of the recovery of Sakinaw Sockeye Salmon, though should be kept to the lowest levels possible.

Although spawning and rearing habitat is currently not limiting Sakinaw Sockeye Salmon productivity, every measure should be taken to protect and to maintain the quality and quantity of Sakinaw Sockeye Salmon spawning and rearing habitat.

Given the high early life history stage mortality and the extremely low marine survival of Sakinaw Sockeye Salmon, minimal allowable harm should be permitted at this time, and be reduced below current levels of harm to the extent possible. This level of harm may allow for some activities to be undertaken while working towards maintaining survival and moving towards recovery of the population. If the Sakinaw Sockeye Salmon enhancement program were discontinued, then no allowable harm should be permitted as the Sakinaw Sockeye Salmon population is currently dependent on the hatchery for survival.

Sources of Uncertainty

Fishing

There is uncertainty in the exploitation rate estimates. Analyses of test fishery data to determine exploitation rate have a lot of uncertainty during years with very low returns (e.g. 1999 onward). There has also been no sensitivity analysis of exploitation rates to changes in migration delay. The estimates also assumed a 100% northern diversion of Sakinaw Sockeye Salmon returns.

The number of Sakinaw Sockeye Salmon caught by First Nations in food, social and ceremonial (FSC) fisheries is unknown because there is no sampling program (e.g. DNA sampling) for fish caught in these fisheries.

Life History information

While survival data for some life history stages are well quantified, there are knowledge gaps for others. For example, there are no natural fry to smolt survival data, and pre-spawn mortality of adults in the lake is unknown. As a result, parameters intended to represent the biology of each life history stage evaluated in the model are known to possess uncertainty which has not necessarily been fully quantified leading to uncertainty in the model structure.

At Sea Mortality

The causes of the very low marine survival rates are unknown. There are hypotheses around the effects of pollutants, high levels of predation, and low ocean productivity due to warm ocean conditions. However, there is high uncertainty in the causal impacts on the survival of Sakinaw Sockeye Salmon.

CONCLUSIONS

Sakinaw Sockeye Salmon experience numerous threats and limiting factors that affect their productivity. Currently, the greatest limiting factor is very low marine survival (<0.5%; smolt to adult). The only way to sustain this stock, under current conditions, and to prevent another extirpation event, is to continue with the captive brood program and the annual release of hatchery fish for the foreseeable future. Given that the population is currently dependent on anthropogenic intervention for survival, a Sakinaw Sockeye Salmon hatchery program review with the intention of identifying opportunities to improve survival through experimentation, as well as identifying clear hatchery origin spawner abundance and genetic broodstock management objectives would be valuable for the continuing survival of the wildlife species as defined by SARA.

SOURCES OF INFORMATION

This Science Advisory Report is from the April 25-26, 2017 Recovery Potential Assessment - Sakinaw Sockeye Salmon. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

COSEWIC. 2016. COSEWIC assessment and status report on the Sockeye Salmon *Oncorhynchus nerka*, Sakinaw population, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii + 39 pp.

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