# PRE-COSEWIC REVIEW OF THE SAKINAW SOCKEYE SALMON *(ONCORHYNCHUS NERKA)* POPULATION 2014

## Context

The Sakinaw Lake population of Sockeye Salmon, *Oncorhynchus nerka*, was designated as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in an emergency listing in 2002 (COSEWIC 2003). Their status was reviewed and confirmed in 2003, with an emergency reassessment in 2006. Though designated endangered by COSEWIC, this population was not listed under the Species at Risk Act (SARA). COSEWIC is currently (2015) re-assessing the status of Sakinaw Sockeye. When an aquatic species is assessed, and Fisheries and Oceans Canada (DFO) is a primary data holder, it is common practice to provide corporately held data in the form of a pre-COSEWIC review. The purpose of this Regional Science Response Process (RSRP) is to review available DFO information relevant to the COSEWIC criterion to assess the status of Sakinaw Sockeye. Results of this RSRP will be made available to COSEWIC, the author(s) of the species status report, and the co-chairs of the applicable COSEWIC Species Specialist Subcommittee.

This Science Response results from the Science Response Process of January 2015 on the Pre-COSEWIC Assessment for Sockeye Salmon Sakinaw Population.

## Analysis and Response

### Review of Designatable Units

Designatable Units are defined by COSEWIC as “A population or group of populations… [that] has attributes that make it “discrete” and evolutionarily “significant” relative to other populations” (COSEWIC 2013). The sockeye population reproducing in Sakinaw Lake (henceforth Sakinaw Sockeye) satisfies both of these criteria for a Designatable Unit. Sockeye Salmon populations are reproductively isolated, reproducing in freshwater lakes that have led to genetic distinction and local adaptation to conditions specific to the respective lakes. Sakinaw Sockeye have been shown to be genetically distinct through genetic variation in allozymes (Wood et al. 1994), microsatellite DNA (Nelson et al. 2003) and mitochondrial DNA (Murray and Wood 2002). Distinctness is also evident in the large smolt size, small adult size, and low fecundity of Sakinaw Sockeye.

### Extent of Occurrence and Area of Occupancy

Extent of Occurrence refers to “the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon” (IUCN 2014). In North America, Sockeye Salmon (not specific to Sakinaw population) occur from the Columbia River in the south to the Nome River, Alaska, in the north. Juveniles tend to remain primarily inshore through September-October, and migrate offshore in late autumn or winter (Burgner, 1991). Sakinaw Sockeye reproduce exclusively in Sakinaw Lake (surface area 6.9 $km^2$) (DFO 2008).

Area of Occupancy is “the area within [a species] 'extent of occurrence' which is occupied by a taxon…”, which reflects the fact that a taxon will not usually occur throughout the area of its extent of occurrence, which may contain unsuitable or unoccupied habitat” (IUCN2014). Area of occupancy for the freshwater phase also falls within Sakinaw Lake, with spawning occurring at specific beaches with a total area of ~2.1 $km^2$ (Grant McBain, DFO, Oceans, Habitat and Enhancement, Madiera Park, BC, pers. comm.). Therefore, all reproduction occurs in Canadian waters. The DFO dam, installed in 1952, imposed a limitation on fluctuation of the depth of the lake. Without the dam the lake would fluctuate +/- 90 cm. The Sakinaw Lake Sockeye population is reproductively isolated from other Sockeye, with no evidence of fragmentation within this population. Juvenile migration to the North Pacific occurs through Johnstone Strait. Returning adult migration is primarily through Johnstone Strait; however, there have been a small number of Sakinaw Sockeye caught in DFO test fishery sets in the Juan de Fuca Strait and Gulf Island areas, suggesting that some small portion of the population return along the southern Vancouver Island approach through the Strait of Georgia.

## Life History Characteristics

Sockeye Salmon are one of the seven Pacific salmon species (Order Salmoniformes, Family Salmonidae) in Canada. They are primarily anadromous, though there are some fully freshwater populations (“Kokanee”). Sockeye exist as reproductively isolated populations, each returning to spawn in their natal freshwater habitats (streams, lakes or tributaries). Juveniles tend to make greater use of freshwater nursery habitat than other Pacific salmon, remaining in freshwater for up to three years before migrating to the Pacific Ocean.

The Sakinaw Sockeye population reproduces in Sakinaw Lake on the Sechelt Peninsula in the Strait of Georgia in southwestern BC (Figure 1). This population is generally smaller at maturity than other sockeye, and has a larger smolt size due to a high level of productivity in Sakinaw Lake. Sakinaw Sockeye usually mature at four years, with small numbers maturing at three or five years. Length at maturity (adult fork length) data are available from 2001 wild-caught adults for the captive brood program, and from 2004, 2005, and 2011 fish tunnel video measurements. Average length for 178 animals between 2001 and 2013 is 55 cm (range 28-84 cm). Data for lengths collected in the most recent years are given in Table 2. Juveniles usually spend one year rearing in the lake (approximately 5% spend two years), followed by two (sometimes three) years maturing at sea before returning to Sakinaw Lake as adults to spawn. Ages of smolts have been collected annually through the DFO Assessment Project (Table 4), divided into clipped (hatchery fish) and unclipped (natural spawner origin fish) (note that hatchery fish weren’t clipped for brood years 2008, 2009 and 2010). In 2010, the unclipped sockeye smolts originated from both hatchery and natural spawners. Kokanee are also known to inhabit Sakinaw Lake.

Sockeye fecundity is in the higher end of the range for Pacific salmon. For females collected for brood stock in 1986, 1987, 2000 and 2001, average fecundity was 2796 (n=69; Murray and Wood 2002). Recent fecundity estimates including brood years (BY) 2000-2002, 2004-2005 and 2010 average 1512 (range 0-3096, n=72). These values fall in the lower range for fecundity for most sockeye populations of 2000 to 5200 eggs (Bergner 1991).

Sakinaw Sockeye spawn from mid-November to mid-December. After egg deposition, females remain over the redds until near death, deterring other females and sometimes males from disturbing the redds. Eggs incubate in gravel, and fry (25-32 mm) emerge between late February and early March, initially feeding in the littoral zone, then moving to the limnetic zone between January and June (Burgner 1991). A recent DFO study examined egg-fry survival (from eyed-egg stage) in gravel at 21 sites on four spawning beaches in Sakinaw Lake in 2013

(Haskin's beach and three subareas of Sharon's beach: Snag, Fraser's and Morgan's). Average egg to fry survival was 78%, ranging from 20% to 100%. Survival of fry to smolts is known from hatchery fry (BY 2001, 2002, 2004-2013), and averages 14.6% (range 1.4% to 32.2%).

Smolts migrate to the Pacific Ocean through Johnstone Strait in spring and remain at sea for two to three years before returning to Sakinaw Lake as adults (most return between late June to early August, but may return as early as mid-May and as late as early September). Average smolt size from 1994 to 1997 was reported by the Sechelt Indian Band to be 122.4 mm, 139.2 mm,
133.0 mm and 129.0 mm in 1994, 1995, 1996, and 1997 respectively (Bates and August 1997 *in* Murray and Wood 2002). Smolt length data from 2014 are presented in Table 3. Smolt age data from 2003-2014 are presented in Table 4.

Average smolt to adult survival rate for sockeye (not specific to the Sakinaw population) reported as roughly 4.5% (Forester 1968). Murray and Wood (2002) reported smolt-adult marine survival for Sakinaw based on BY 1992 and 1995 smolt counts and 1996 and 1999 escapements (not separated into fishery and natural mortality) estimated at 0.83%. Data from recent years shows a smolt to adult survival (marine survival) average of 0.28% (BY 2001, 2004-2010) for hatchery and 0.40% (BY 2001, 2002, 2004-2006; Table 5) for natural origin sockeye. These rates are below what is required for natural sustainable levels

Adult spawners hold in the lake for up to four months before spawning (Murray and Wood 2002). In–lake mortality during holding is unknown, but is assumed to be very low. Dive counts have been conducted, but are often unreliable estimates of fish present and associated in-lake survival, because some fish may be missed on dive surveys and not all beaches are surveyed (Table 6). However, in years with low returns, when thorough dive counts were conducted, (2004 and 2005), the number of fish counted at the fishway and on later dive surveys suggest that mortality is 10% or less.

## Habitat Characteristics

Sakinaw Lake is in the Sechelt region with a climate characterized by warm, dry summers and mild, wet winters. The lake consists of two basins. The upper basin has a maximum depth of 40 m, and the lower basin has a maximum depth of 140 m and mean depth of 43 m. Sakinaw Lake is classified as meromictic, meaning that it remains stratified with a fresher surface layer and saline deeper layer that do not mix. Below 30 m depth, water is warmer and is partially saline (up to approximately 11%) and anoxic.

In 1952, DFO installed a dam at the outlet of Sakinaw Lake. The dam is actively managed by DFO to maximize water storage levels in the summer period and to facilitate salmon migration June-October.

Specific beaches in the lake are used by spawning adult sockeye, as identified in 1979, 1999, 2000 and 2001 DFO dive surveys reported in Murray and Wood (2002) and subsequent surveys (Figure 2). Recent surveys have shown that only two of the original five beaches are still actively used. At spawning, Sakinaw Sockeye require beaches with gravel small enough to be moved when digging and with sufficient flow of oxygenated waters. Too much fine sediment in spawning substrate can lead to poor water exchange and low oxygen and high metabolic wastes. Upwelling ground water is essential for successful beach spawning in Sakinaw Lake. Spawning occurs from 25 cm from the lake water surface down to 25 m, with the majority of redds occurring between 3-10 m (Burgner 1991).

There are five known spawning beaches, three in the upper basin (Sharon's, Haskin's and Ruby) and two in the lower basin (Prospector's and Kokomo) of the lake and near stream inlets or groundwater sources. The three upper beaches have been reported to be used for spawning, though in 2001 surveys, Ruby wasn't being used. The remaining beaches appeared to be of poor quality for spawning (surveys as reported in Murray and Wood 2002). 2003-2004 dive surveys assessed nine different sites around the lake. Suitable spawning habitat and conditions were identified, yet some sites appeared not to be used. The upland area from Sharon's beach has been owned by the same family since 1952, and has shown no impacts by residential development or logging. Spawning habitat at this site, however, has been impacted by falling trees and heavy woody debris. Haskin's beach was impacted when "Boat ramp" creek was diverted from its original channel to install the boat ramp, but sockeye still try to spawn in the original spawning bed associated with the channel. DFO has undertaken recent restoration efforts to enhance spawning habitat at known beaches (Sharon's and Haskin's), including clearing of fallen trees from original flooding, woody debris, large rocks and accumulated sediment and loosening of compacted gravel from marked redds.

## Population trends

Counts of mature sockeye for population estimates are usually taken as the number of spawners that escape fisheries and return to the lake to spawn (Table1). Data were compiled from DFOBC-16s[1] from 1947-1994. Reliable estimates do not exist for 1995, 1997 and 1998. A partial count in 1996, and complete count in 2002 were made through the fishway in the dam, and 1999-2001 estimates were made by dive survey counts at spawning beaches. Since 2003, counts were made from a digital video system, in the fishway. Estimates at spawning beaches are, presumably, biased by in-lake mortality. This is an unavoidable bias between return estimates at the fishway and estimates at the spawning grounds with an approximate magnitude of up to 10%. Fishway counts provide the highest quality data to inform assessments.

Numbers of mature Sakinaw Sockeye from 1947-1987 showed no apparent trend, varying from 750-16,000 (Table 1). After 1987, escapements declined drastically until 2006 when 0 or 1 adult returned to the lake each year from 2006-2009. Given that the generation time for sockeye is four years, the population went extinct in the wild.

During the collapse of the population, a captive brood program was initiated to supplement the declining returns. Wild adults (n=84) were used to establish this captive population from escapement in 2002-2005 (Withler et al. 2014). The entire Sakinaw population is now descended from the captive population. Hatchery fry are released into the upper basin of Sakinaw Lake annually, with subsequent smolt enumeration and adult returns assessment. Between 29 and 554 of hatchery-released fish returned to spawn from 2010 to 2014. Numbers of fry released from hatcheries from 2001-2014, as well as smolt counts out-migrating from the lake from 2003-2014, are provided in Table 5. 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. Hatchery fry were not clipped 2009-2011 as all returns in 2012-2103 are assumed to have originated from hatchery. Sixteen reintroduced adults spawned naturally in the lake in 2010, but resulting smolts were not discernable from hatchery fish (Withler et al. 2014). Clipping resumed in 2012.

[1] BC16s are the individual records where salmon spawning counts are recorded for each stream. Data from these reports are housed in DFO regionally managed NuSEDS database.

Hatchery fry from the captive brood program continue to be produced to supplement natural recruitment while escapements remain low. Hatchery fry released between 2001 and 2014 varied from 0 to 1,373,822 fry (Table 5). Smolts counted out-migrating from the lake between 2003 and 2014 range from 13 smolts in 2005 to 252,535 smolts in 2011. The ongoing smolt enumeration and adult return assessment, combined with adipose clipping to discern between hatchery and natural spawned fish, provide valuable data to assess freshwater and marine survival of both naturally-spawned and hatchery-produced fish. Based on these data, the estimates of survival indicate that the current bottleneck for Sakinaw Sockeye recovery is in the marine environment, though specific causes are unknown (Withler et al. 2014). The collection of these valuable data results from a strong collaboration between the Sechelt Band, Salmonid Enhancement Program, and DFO Science.

Sakinaw Sockeye co-occur with migrating Fraser River Sockeye in Johnstone Strait and these stocks are therefore co-managed. DFO has altered fisheries management practices to reduce impacts of salmon fisheries for Sakinaw Sockeye in the marine phase. The following excerpt from a draft DFO report updating the conservation strategy for Sakinaw Sockeye summarizes fisheries management efforts to minimize exploitation of Sakinaw in the mixed fishery (Andrea Goruk, DFO, Fisheries Management, Nanaimo, BC, pers. comm.):

*"Sakinaw Lake sockeye are considered most vulnerable to harvest directed at Fraser River stocks through to late July. To protect Sakinaw Lake Sockeye most potential interception fisheries (commercial and recreational) are delayed until the last week of July to ensure a significant proportion of the return has passed through the major fisheries in Johnstone Strait. There are sockeye non-retention restrictions in Area 16 until early to mid-August. Commercial fisheries in the upper Strait of Georgia are closed until early to mid-August. The waters near the mouth of Sakinaw Creek are closed to fishing all season. The Sechelt First Nation coordinates fisheries to avoid periods and areas of concern for Sakinaw Sockeye. There is a high level of compliance with these actions".*

## Residence

SARA s. 2(1) 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." Sakinaw Sockeye spawn exclusively in Sakinaw Lake in BC, Canada. Females build redds for egg deposition directly in the gravel substrate on beaches of this lake only. As such these areas could be considered as residence.

## Threats to Abundance

The primary threat to the Sakinaw sockeye population is survival in the marine environment. Proportions of mortality related to natural limiting factors, fishing mortality and lake entry challenges for returning adults are unknown. Factors previously identified as potentially influential in the population decline include the non-operation of the fishway, exploitation rates and poor ocean conditions (Withler et al. 2014).

Exploitation through mixed stock fisheries at sea is believed to have contributed to the decline of Sakinaw Sockeye in the past, with high fishing effort and harvest rate in the Strait of Georgia and Johnstone Strait through which Sakinaw Sockeye migrate. Data for exploitation rates depend on a suite of variables, including catch, scale racial analysis and escapement. Using data collected between 1970-2001, Murray and Wood (2002) estimated harvest rates at 37-65% for Johnstone Strait, and 4-29% from Area 16 in the Strait of Georgia, and exploitation rates of

Sakinaw sockeye ranging from 1-67% between 1970-1999. Peer reviewed exploitation rates on Sakinaw Sockeye for recent years are not available.

Migration into Sakinaw Lake via the DFO storage dam and fishway at the lake outlet was impacted throughout the 1990's due to lack of DFO staff required to operate the storage dam and fishway. The fishway trap at the dam (deployed in 1987-88, not used for several years and removed 1996-97) and the fishway itself can facilitate predation by otters and humans. In 1995, DFO installed two rock weirs downstream of the dam to increase the pool depth below the fishway by two metres and reduce the jumps into the fishway from 8 – 30 cm jumps to less than 3 – 30cm. Ongoing monitoring (manned presence) is necessary during migration to minimize predation as a source of mortality. Staffing is also needed to adjust fishway flows as the lake levels drop, and clear any obstacles.

Natural predation, both in the lake and at sea by birds, fish and mammalian predators, can also impact population numbers (Murray and Wood 2002). Fish predators of juvenile sockeye include cutthroat trout, juvenile Coho and Chinook, Prickly Sculpin and lamprey. Birds that prey on juvenile Sockeye include terns, gulls, mergansers, loons, cormorants, grebes, kingfishers, osprey and Bald Eagles. Among potential mammalian predators are river otters, seals, mink and bears.

There is no evidence that all the causes for the decline has ceased. However, it is believed that the declines are reversible, with continued operation of the dam and fishway, habitat restoration efforts, monitoring and reduction of juvenile predation, management of water flows, and fishery management practices that limit fishing mortality. However, marine survival is currently insufficient to sustain the population without hatchery supplementation.

## Conclusions

Sakinaw sockeye is being re-assessed by COSEWIC. This Science Response is intended to inform that process. Sakinaw sockeye were extirpated from the wild 2006-2009, and were successfully reintroduced from a captive breeding program (Withler et al. 2014). Although nearly 500 adults returned in 2014, and more than 500 returned in 2011, the population is still under threat. Current survival rates from smolt to adult are not sufficient to sustain the population (Withler et al. 2014), and continued hatchery supplementation is likely required to prevent another extirpation event until survival in the marine environment improves. Spawning habitat has in the past been affected by operating the lake storage at fixed levels, the original flooding of the lake and land development. Restoration work at spawning beaches, since the population declined, has improved the extent of spawning habitat. Ensuring effective operation of the storage dam and fishway to ensure adult access is important. Freshwater factors are currently believed to have a limited to negligible impact on population survival, however, further research is warranted. Low smolt to adult survival in the ocean, due to natural and likely to a much lesser extent, fishing mortality, continues to be the major factor in preventing recovery (Withler et al. 2014).

## Contributors

| Name | Affiliation |
|---|---|
| Sean MacConnachie | DFO, Science (Chair) |
| Elise Keppel | Lead Author |
| Steve Baillie | DFO, Stock Assessment |

| Name | Affiliation |
|---|---|
| Dave Bates | Shíshálh (Sechelt) First Nation |
| Andrea Goruk | DFO, Fisheries Management |
| Grant McBain | DFO, Oceans, Habitat and Enhancement |
| Dave O'Brien | DFO, Stock Assessment |
| Marilyn Hargeaves (Editor) | DFO, Centre for Science Advice Pacific, Coordinator |

## Approved by

Carmel Lowe
Regional Director
Science Branch, Pacific Region
Fisheries and Oceans Canada

March 24, 2015

## Sources of information

Burgner, R. L. 1991. Life history of Sockeye Salmon *(Oncorhynchus nerka)*. Pacific salmon life histories, 3-117.

COSEWIC. 2003. 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. ix + 35 pp. (Accessed March 14, 2015)

COSEWIC. 2013. Guidelines for Recognizing Designatable Units. (Accessed March 14, 2015)

Forester, R.E. 1968. The Sockeye Salmon, *Oncorhynchus nerka*. Fish. Res. Board Can. Bull. 162:422 p.

IUCN 2014. Red List of Categories and Criteria, Version 3.1. Prepared by the International Union for the Conservation of Nature Species Survival Commission. (Accessed April 10, 2015).

Murray, C., Wood, C.C. 2002. Status of Sakinaw Lake Sockeye Salmon *(Oncorhynchus nerka)*. DFO Can. Sci. Advis. Sec. Res. Doc. 2002/088. viii + 100 p.

Nelson, R.J., Wood, C.C., Cooper, G., Smith, C., & Koop, B. 2003. Population structure of Sockeye Salmon of the central coast of British Columbia: implications for recovery planning. North Amer. J. Fish. Manag. 23:703–720.

Withler, R.E., O'Brien, D.S., Watson, N.M., & Supernault, K.J. 2014. Maintenance of Genetic Diversity in Natural Spawning of Captively-Reared Endangered Sockeye Salmon, *Oncorhynchus nerka*. Diversity 6:354-379.

Wood, C.C., Riddell, B.E., Rutherford, D.T., & Withler, R.E. 1994. Biochemical genetic survey of Sockeye Salmon *(Oncorhynchus nerka)* in Canada. Can. J. of Fish. Aquat. Sci. 51(S1):114-131.

# Appendix A –Tables and Figures

*Table 1. Sakinaw sockeye adult counts. 1947-1994 counts are from BC-16 data. Insufficient data exists for 1995, 1997 and 1998. 1996 and 2002 counts used a fishway trap. 1999-2001 estimates 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). 2003-2014 counts are from a digital video system set up in the fishway. "Estimate class" represents quality associated with the data collection: U = Unknown data collection; Type 1 data are a very good population estimate (nearly every fish counted through video tunnel); Type 2 data are still a very good population estimate (nearly every fish counted through video tunnel or fishway trap with perhaps a small portion of the population missed); Type 4 data are missing some days at the end of the migration when some fish may still be going through the fishway but are still a reasonable estimate of the population; Type 6 data are reliable for presence/absence only.*

| Year | Estimate Class | Clipped Jacks | Unclipped Jacks | Clipped Adults | Unclipped Adults | Total |
|---|---|---|---|---|---|---|
| 1947 | U | - | - | - | 3500 | 3500 |
| 1948 | U | - | - | - | 4600 | 4600 |
| 1949 | U | - | - | - | 3931 | 3931 |
| 1950 | U | - | - | - | 2473 | 2473 |
| 1951 | U | - | - | - | 3450 | 3450 |
| 1952 | U | - | - | - | 6222 | 6222 |
| 1953 | U | - | - | - | 1131 | 1131 |
| 1954 | U | - | - | - | 4143 | 4143 |
| 1955 | U | - | - | - | 5079 | 5079 |
| 1956 | U | - | - | - | 2150 | 2150 |
| 1957 | U | - | - | - | 4300 | 4300 |
| 1958 | U | - | - | - | 4250 | 4250 |
| 1959 | U | - | - | - | 13000 | 13000 |
| 1960 | U | - | - | - | 4500 | 4500 |
| 1961 | U | - | - | - | 750 | 750 |
| 1962 | U | - | - | - | 3500 | 3500 |
| 1963 | U | - | - | - | 7500 | 7500 |
| 1964 | U | - | - | - | 3500 | 3500 |
| 1965 | U | - | - | - | 750 | 750 |
| 1966 | U | - | - | - | 3500 | 3500 |
| 1967 | U | - | - | - | 6000 | 6000 |
| 1968 | U | - | - | - | 14000 | 14000 |
| 1969 | U | - | - | - | 1200 | 1200 |
| 1970 | U | - | - | - | 5000 | 5000 |
| 1971 | U | - | - | - | 8000 | 8000 |
| 1972 | U | - | - | - | 4500 | 4500 |
| 1973 | U | - | - | - | 1500 | 1500 |
| 1974 | U | - | - | - | 6000 | 6000 |
| 1975 | U | - | - | - | 16000 | 16000 |
| 1976 | U | - | - | - | 6000 | 6000 |

| Year | Estimate Class | Clipped Jacks | Unclipped Jacks | Clipped Adults | Unclipped Adults | Total |
|---|---|---|---|---|---|---|
| 1977 | U | - | - | - | 1200 | 1200 |
| 1978 | U | - | - | - | 4000 | 4000 |
| 1979 | U | - | - | - | 11000 | 11000 |
| 1980 | U | - | - | - | 2800 | 2800 |
| 1981 | U | - | - | - | 3000 | 3000 |
| 1982 | U | - | - | - | 3400 | 3400 |
| 1983 | U | - | - | - | 1600 | 1600 |
| 1984 | U | - | - | - | 1115 | 1115 |
| 1985 | U | - | - | - | 2400 | 2400 |
| 1986 | U | - | - | - | 5400 | 5400 |
| 1987 | U | - | - | - | 4200 | 4200 |
| 1988 | U | - | - | - | 2500 | 2500 |
| 1989 | U | - | - | - | 1000 | 1000 |
| 1990 | U | - | - | - | 1200 | 1200 |
| 1991 | U | - | - | - | 500 | 500 |
| 1992 | U | - | - | - | 1000 | 1000 |
| 1993 | U | - | - | - | 250 | 250 |
| 1994 | U | - | - | - | 250 | 250 |
| 1995 | NI | - | - | - | - | - |
| 1996 | Type 4 | - | - | - | 222 | 222 |
| 1997 | Type 6 | - | - | - | Present, not counted | Present, not counted |
| 1998 | Type 6 | - | - | - | Present, not counted | Present, not counted |
| 1999 | Type 4 | - | - | - | 14 | 14 |
| 2000 | Type 4 | - | - | - | 112 | 112 |
| 2001 | Type 4 | - | - | - | 87 | 87 |
| 2002 | Type 2 | - | - | - | 78 | 78 |
| 2003 | Type 1 | - | - | - | 3 | 3 |
| 2004 | Type 1 | - | - | 0 | 99 | 99 |
| 2005 | Type 1 | - | - | 7 | 21 | 28 |
| 2006 | Type 1 | - | - | 0 | 1 | 1 |
| 2007 | Type 1 | - | - | 0 | 0 | 0 |
| 2008 | Type 1 | - | - | 0 | 0 | 0 |
| 2009 | Type 1 | - | - | 1 | 0 | 1 |
| 2010 | Type 2 | - | - | 28 | 1 | 29 |
| 2011 | Type 1 | - | - | 555 | 0 | 555 |
| 2012 | Type 2 | - | - | 0* | 243* | 243 |
| 2013 | Type 1 | - | 29 | 0* | 114* | 143 |
| 2014 | Type 1 | 10 | 2 | 0* | 452* | 464 |

* = Hatchery fish were not clipped BY 2008-2010.

*Table 2. Sakinaw Sockeye adult length, collected from digital video system in the Sakinaw Lake fishway.*

| Length (cm) | Frequency | | |
|---|---|---|---|
| | 2004 | 2005 | 2013 |
| 26-30 | 0 | 1 | 0 |
| 31-35 | 0 | 1 | 2 |
| 36-40 | 0 | 6 | 10 |
| 41-45 | 1 | 0 | 11 |
| 46-50 | 14 | 3 | 9 |
| 51-55 | 48 | 11 | 6 |
| 56-60 | 32 | 15 | 15 |
| 61-65 | 3 | 3 | 17 |
| 66-70 | 0 | 4 | 22 |
| 71-75 | 0 | 0 | 3 |
| 76-80 | 0 | 0 | 3 |
| 81-85 | 0 | 0 | 1 |
| n | 98 | 44 | 99 |
| Min | 44 | 28 | 35 |
| Mean | 54.1 | 53.3 | 57.2 |
| Max | 63 | 69 | 84 |

*Table 3. Sakinaw Sockeye average smolt fork length (in mm) 2014.*

| Smolt Year | Unclipped Sockeye | | Clipped Sockeye | |
|---|---|---|---|---|
| | Age 1 | Age 2 | Age 1 | Age 2 |
| 2003 | 120 | 128 | 118 | 151 |
| 2004 | 115 | 136 | 138 | 157 |
| 2005 | - | - | - | - |
| 2006 | 120 | 130 | 128 | 129 |
| 2007 | 139 | - | 151 | - |
| 2008 | 153 | - | 136 | 161 |
| 2009 | 145 | - | 141 | - |
| 2010 | 121* | 152 | - | 155 |
| 2011 | 123 | 143* | - | - |
| 2012 | 115** | 121* | - | - |
| 2013 | 111 | 146** | 112 | 121 |
| 2014 | 117 | 134 | 116 | 131 |

* Unclipped hatchery release
** Mix of unclipped hatchery release and natural spawner progeny

*Table 4. Sakinaw Sockeye smolt ages 2003-2014.*

| Smolt Year | Unclipped Sockeye | | | Clipped Sockeye | | |
|---|---|---|---|---|---|---|
| | Age 1 | Age 2 | Total | Age 1 | Age 2 | Total |
| 2003[a] | 4194 | 140 | 4334 | 8080 | 0 | 8080 |
| 2004[a] | 84 | 19 | 103 | 12 | 28 | 40 |
| 2005[b] | 0 | 11 | 11 | 0 | 2 | 2 |
| 2006[a] | 2891 | 35 | 2926 | 7207 | 1150 | 8357 |
| 2007[b] | 272 | 0 | 272 | 3739 | 0 | 3739 |
| 2008[c] | 182 | 0 | 182 | 11630 | 352 | 11982 |
| 2009[c] | 222 | 0 | 222 | 62368 | 0 | 62368 |
| 2010[c] | 63032 | 6506 | 69538 | 0 | 404 | 404 |
| 2011[c] | 29783 | 3109 | 32892 | 0 | 0 | 0 |
| 2012[c] | 161493 | 1384 | 162877 | 0 | 0 | 0 |
| 2013[c] | 19759 | 8200 | 27960 | 214043 | 10532 | 224575 |
| 2014[c] | 4168 | 266 | 4435 | 117994 | 3615 | 121610 |

a = stratify by length, b = no stratification, c = stratify by time

*Table 5. Hatchery fry released, smolt counts and survival rates.*

| | Fry released | | | Smolt count | | | Survival % | | |
|---|---|---|---|---|---|---|---|---|---|
| Brood year | Natural origin brood | Captive brood | Total | Clipped | Unclipped | Total | Hatchery fry to smolt | Marine (hatchery - clipped) | Marine (natural origin - unclipped) |
| 1992 | - | - | - | - | 15880 | 15880 | - | - | - |
| 1993 | - | - | - | - | 2760 | 2760 | - | - | - |
| 1994 | - | - | - | - | 2500 | 2500 | - | - | - |
| 1995 | - | - | - | - | 5200 | 5200 | - | - | - |
| 1996 | - | - | - | - | - | - | - | - | - |
| 1997 | - | - | - | - | - | - | - | - | - |
| 1998 | - | - | - | - | - | - | - | - | - |
| 1999 | - | - | - | - | - | - | - | - | - |
| 2000 | 14981 | 0 | 14981 | - | - | - | - | - | - |
| 2001 | 31922 | 0 | 31922 | 8080 | 4334 | 12414 | 25.31% | 0.087% | 0.485% |
| 2002 | 2784 | 0 | 2784 | 39 | 103 | 142 | 1.40% | 0.000% | 0.971% |
| 2003 | 0 | 0 | 0 | 2 | 11 | 13 | n/a | n/a | n/a |
| 2004 | 25927 | 0 | 25927 | 8357 | 2926 | 11283 | 32.23% | 0.000% | 0.000% |
| 2005 | 7588 | 87877 | 95465 | 3739 | 272 | 4011 | 3.92% | 0.027% | 0.000% |
| 2006 | 0 | 84626 | 84626 | 11982 | 182 | 12164 | 14.16% | 0.234% | 0.549% |
| 2007 | 0 | 420781 | 420781 | 62370 | 222 | 62592 | 14.88% | 0.890% | n/a |
| 2008 | 0 | 726376 | 726376 | 404 | 69538 | 69942 | 9.63% | 0.347% | n/a |
| 2009 | 0 | 329360 | 329360 | 0 | 32892 | 32892 | 9.99% | 0.347% | n/a |
| 2010 | 5110 | 1368712 | 1373822 | 0 | 162877 | 162877 | 11.86% | 0.278% | n/a |
| 2011 | 0 | 963328 | 963328 | 224575 | 27960 | 252535 | 23.31% | - | - |
| 2012 | 0 | 856205 | 856205 | 121468 | 4435 | 125902 | 14.19% | - | - |
| 2013 | 0 | 320416 | 320416 | - | - | - | - | - | - |

*Table 6. Fishway counts as fish enter the lake and dive counts. Dive counts are not reliable estimates of number of fish in the lake or associated in-lake mortality given the difficulty in finding the fish in a large lake and number of days between dives.*

| Year | Fishway Count | Dive Count Total |
|---|---|---|
| 1999 | No count | 0 |
| 2000 | No count | 20 |
| 2001 | 60 | 29 |
| 2002 | 78 | 43 |
| 2003 | 3 | No dives |
| 2004 | 99 | 91 |
| 2005 | 24 | 22 |
| 2006 | 1 | No dives |
| 2007 | 0 | No dives |
| 2008 | 0 | No dives |
| 2009 | 1 | 0 |
| 2010 | 29 | 24 |
| 2011 | 554 | 465 |
| 2012 | 244 | 219 |
| 2013 | 143 | 135 |
| 2014 | 464 | 286 |

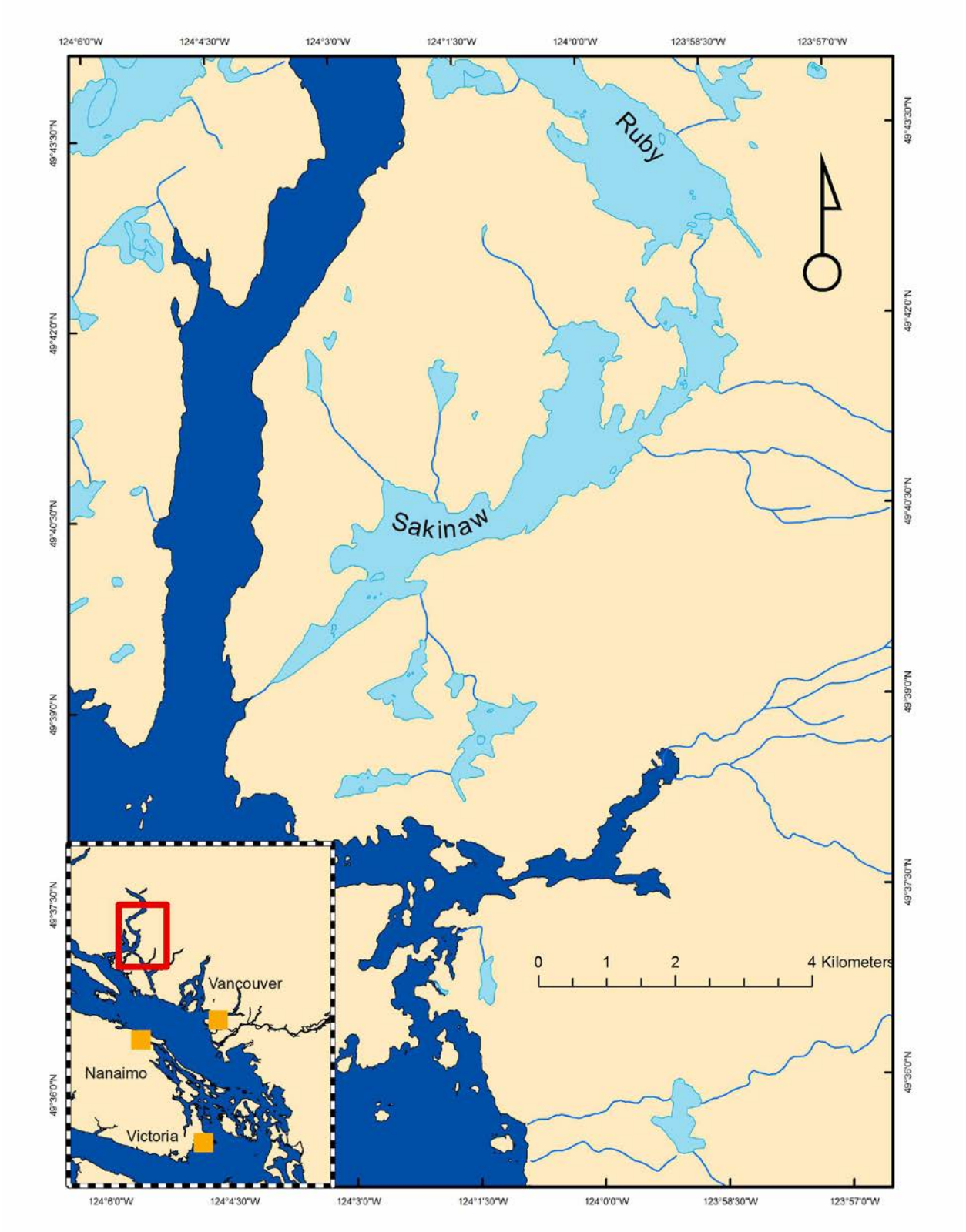


*Figure 1 Sakinaw Lake (light blue) located on the Sechelt Peninsula, BC coast. Strait of Georgia is to the west (dark blue).*

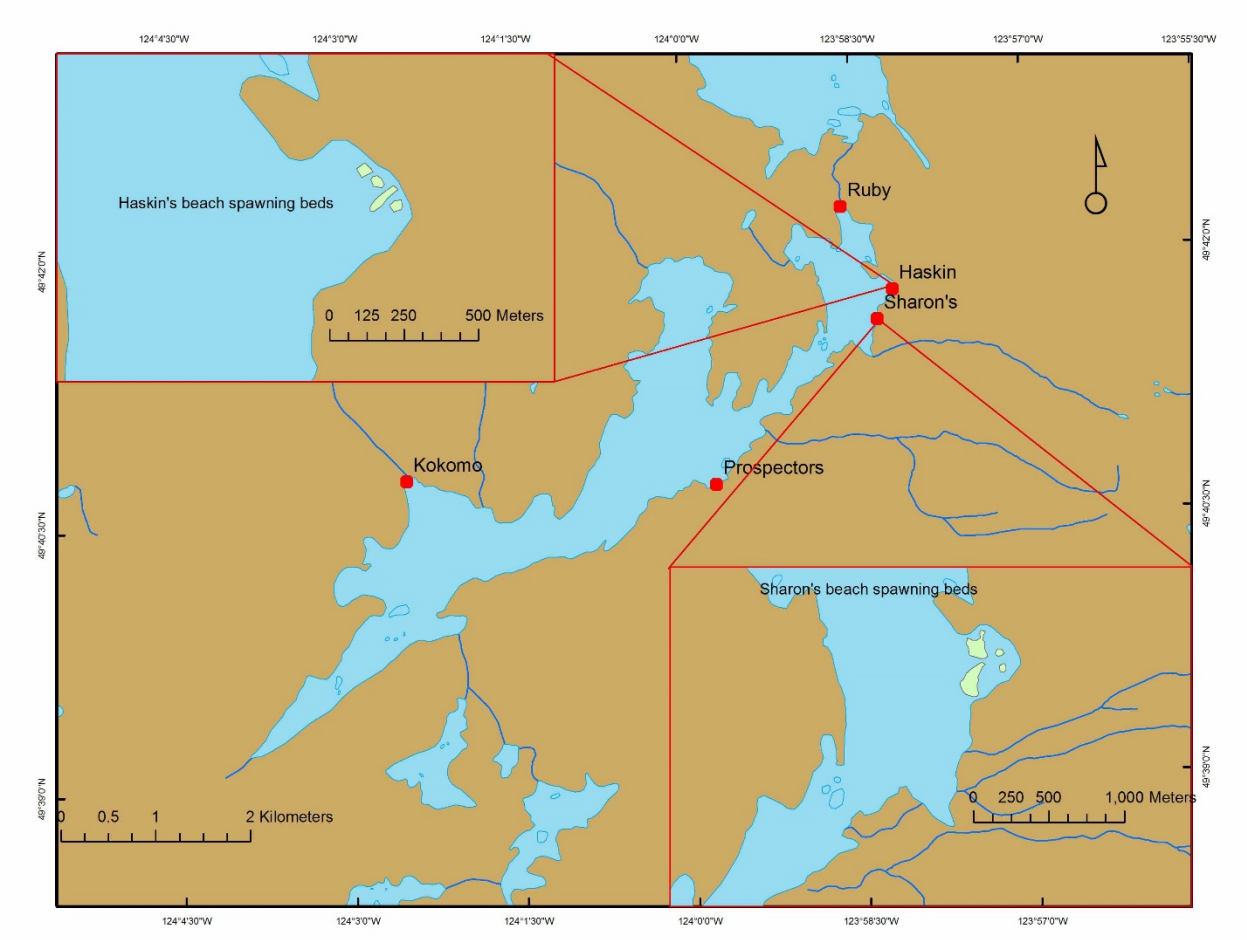


*Figure 2. Sakinaw Lake spawning beaches. Spawning is currently known to occur at Sharon's, Haskin's and occasionally at Ruby beach. Green polygons represent spawning beds.*

## This Report is Available from the

Centre for Science Advice
Pacific Region
Fisheries and Oceans Canada
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

Telephone: 250-756-7208
E-Mail: csap@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-3769
© Her Majesty the Queen in Right of Canada, 2015

Correct Citation for this Publication:

DFO. 2015. Pre-COSEWIC Review of the Sakinaw Sockeye Salmon *(Oncorhynchus nerka)* Population 2014. DFO Can. Sci. Advis. Sec. Sci. Resp. 2015/020.

*Aussi disponible en français :*

*MPO. 2015. Examen pré-COSEPAC de la population du saumon rouge (Oncorhynchus nerka) du lac Sakinaw en 2014. Secr. can. de consult. sci. du MPO, Rép. des Sci. 2015/020.*