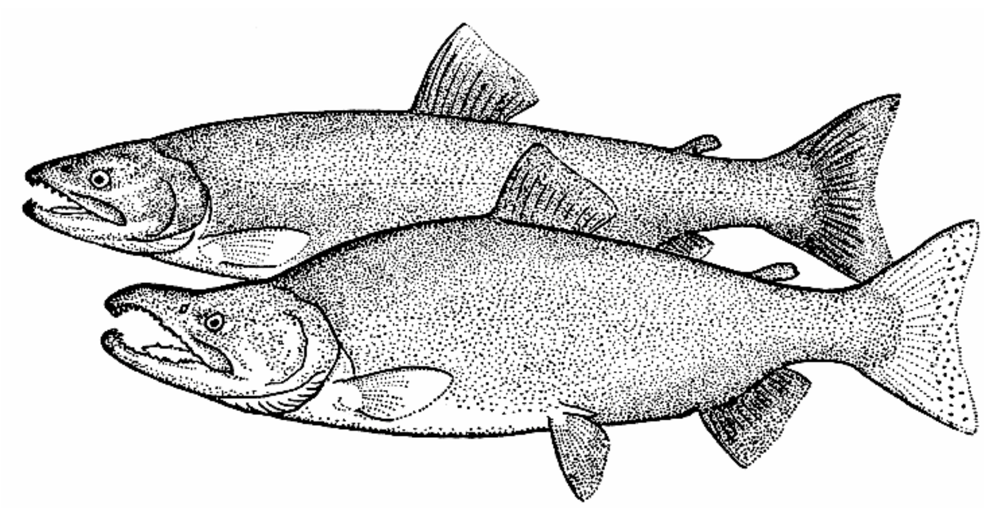
COSEWIC
Assessment and Status Report

on the

Sockeye Salmon
Oncorhynchus nerka

Sakinaw population

in Canada



ENDANGERED
2016

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Previous report(s):

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.

Production note:
COSEWIC would like to acknowledge Jacob (Jake) Schweigert for writing the status report on Sockeye Salmon (Sakinaw population). This report was prepared under contract with Environment Canada and was overseen by Alan Sinclair, Co-chair of the COSEWIC Marine Fishes Specialist Subcommittee.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur le Saumon sockeye (*Oncorhynchus nerka*), population Sakinaw, au Canada.

Cover illustration/photo:
Sockeye Salmon — Mature Sockeye Salmon (female above, male below) (reprinted from Scott and Crossman, 1973).

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COSEWIC
Assessment Summary

Assessment Summary – May 2016

Common name
Sockeye Salmon - Sakinaw population

Scientific name
Oncorhynchus nerka

Status
Endangered

Reason for designation
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.

Occurrence
British Columbia, Pacific Ocean

Status history
Designated Endangered in an emergency assessment on 20 October 2002. Status re-examined and confirmed in May 2003. Status re-examined in an emergency reassessment on 20 April 2006 and confirmed Endangered. Status re-examined and confirmed in April 2016.

COSEWIC
Executive Summary

Sockeye Salmon
Oncorhynchus nerka

Sakinaw population

Wildlife Species Description and Significance

The status report evaluates the distinct population of Sockeye Salmon that inhabits Sakinaw Lake, British Columbia (henceforth called Sakinaw Sockeye). Protein electrophoresis and molecular DNA analyses indicate that Sakinaw Sockeye are genetically distinct and substantially reproductively isolated from other British Columbia (BC) Sockeye Salmon populations. Sakinaw Sockeye possess a suite of life history characteristics including early, but protracted, timing of river-entry, extended lake residency prior to spawning, small body size, low fecundity and large smolt size, supporting their evolutionary distinctiveness from other sockeye populations and consideration as a designatable unit (DU).

The conservation of Sakinaw Sockeye is a high priority for the Sechelt First Nation because these fish return to reproduce within Sechelt traditional territory. Sockeye Salmon may also play a significant role in maintaining the productivity of the Sakinaw Lake ecosystem by importing marine derived nutrients and contributing to the lake's food web.

Distribution

Sakinaw Sockeye are endemic to Canada, reproducing exclusively within Sakinaw Lake, situated on the Sechelt Peninsula in the Strait of Georgia, BC where they remain for two or three years (over half their life). Sakinaw Sockeye are anadromous, sharing marine migration corridors and foraging habitat in the North Pacific Ocean with many other Sockeye Salmon populations.

Habitat

Sakinaw Sockeye require suitable spawning and juvenile rearing habitat within Sakinaw Lake, and foraging habitat for smolt and immature adults in the North Pacific Ocean to attain adult size with unobstructed passage between them. Sakinaw Sockeye spawn entirely within the lake on one or two beaches near creeks or other sources of groundwater.

Biology

Sakinaw Sockeye mostly spawn in late November through mid-December. All die after spawning and carcasses are eaten or decompose in the lake. Eggs and alevins remain buried in gravel during the winter. Fry emerge in March and April and move to limnetic habitat to feed on zooplankton. Emergence is synchronized with spring plankton blooms requiring that spawning time and/or embryonic development rate be genetically adapted to ambient temperature regimes in the spawning environment.

Most Sakinaw Sockeye mature at age 4 (end of their 4th year of life) following two winters in the ocean, returning to Sakinaw Lake in June through early September. Adults are small at maturity compared with most other sockeye populations in Canada, and fecundity is at the low end of the species' range.

Population Sizes and Trends

From 1947 to 1987, the estimated number of maturing adults entering Sakinaw Lake averaged about 4,500 individuals (range 750 to 16,000) with no declining trend. From 1987 to 2005, numbers declined dramatically and from 2006 to 2009 there were zero or one adult Sockeye counted entering the lake and the population became extirpated in the wild. A captive-breeding program began in 2002 and it has preserved the population. Adult Sockeye Salmon from the hatchery releases began returning to Sakinaw Lake in 2010, with a total of 29 spawners counted at the fishway. Between 2011 and 2014, an annual average of 351 (range 114 to 555) captively bred adult fish returned to the lake. Some of these fish were observed spawning on historical beaches. It is too early to determine if their offspring have succeeded in returning to the lake to spawn again.

Threats and Limiting Factors

The recovery and persistence of the Sakinaw Sockeye population is threatened by two primary factors: mortality in the marine environment, and degradation of freshwater habitat. Poor survival in the ocean and fishing mortality remain the two significant threats. Reduced marine survival is evident for many Sockeye Salmon populations in the eastern Pacific Ocean during the 1990s. Some Sakinaw Sockeye continue to be killed in fisheries, and given their very low abundance, even modest fishing mortality jeopardizes the viability of the population.

Protection, Status and Ranks

In 2002, COSEWIC assessed Sakinaw Sockeye as Endangered but the Government of Canada did not list it under the *Species at Risk Act* in 2005. However, the Wild Pacific Salmon Policy was developed and adopted to promote the long-term viability of Pacific salmon populations and their natural habitat. A Sakinaw Sockeye Salmon Recovery Team was established to develop a recovery plan and many of the recommendations have been implemented. The plan has been updated and revised recently and continues to support conservative fishing and maintenance of the captive breeding program. NatureServe lists Sakinaw Sockeye Salmon as Critically Imperilled (T1) as of 2005 and the American Fishery Society status is endangered as of 2008.

TECHNICAL SUMMARY

Onchorhyncus nerka

Sockeye Salmon – Sakinaw population

Range of occurrence in Canada (province/territory/ocean): British Columbia (Sakinaw Lake, Sechelt Peninsula); Pacific Ocean

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2011) is being used)	4 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No. The population became extirpated in the wild in 2009.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	There has been a decline of 100% of mature individuals over the past 2 generations.
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Wild adult returns declined by 100% over the past 3 generations.
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	NA. It is unclear if returns from captive bred individuals can reproduce successfully in the wild and it is not possible to predict future returns of non-captive bred individuals.
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	NA. It is unclear if returns from captive bred individuals can reproduce successfully in the wild and it is not possible to predict future returns of non-captive bred individuals.
Are the causes of the decline a.clearly reversible and b.understood and c. ceased?	a. No. Low marine survival not readily reversed. b. No. The mechanism affecting low marine survival is not understood. c. No. Marine survival remains low.
Are there extreme fluctuations in number of mature individuals?	No.

Extent and Occupancy Information

Estimated extent of occurrence	>20000 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	~4 km² based on spawning grounds
Is the population “severely fragmented” ie. is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No, the population is endemic to single lake. b. No.

Number of “locations” (use plausible range to reflect uncertainty if appropriate)	One (Sakinaw Lake) but captive breeding population maintained at Rosewall hatchery.
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Unknown but possible given the reduction in the abundance of the population.
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes, there has been a contraction in the spawning sites used.
Is there an [observed, inferred, or projected] decline in number of subpopulations?	No.
Is there an [observed, inferred, or projected] decline in number of “locations”*?	No.
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes. The area of available suitable spawning habitat has declined significantly since 1979. However, there have been recent and ongoing efforts to remove debris from a couple of spawning beaches.
Are there extreme fluctuations in number of subpopulations?	No.
Are there extreme fluctuations in number of “locations”∗?	No.
Are there extreme fluctuations in extent of occurrence?	Unknown.
Are there extreme fluctuations in index of area of occupancy?	No.

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	
	The number of wild-bred returning adults is less than 250.
Total	<250

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Quantitative analysis not conducted as population extirpated in the wild, currently supported by captive breeding program.

Threats (actual or imminent, to populations or habitats, from highest impact to least)

i. Low marine survival
ii. Fishery exploitation

Was a threats calculator completed for this species and if so, by whom? No.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	DU is found only in Canada.
Is immigration known or possible?	No.
Would immigrants be adapted to survive in Canada?	No.

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Is there sufficient habitat for immigrants in Canada?	Yes.
Are conditions deteriorating in Canada?[+]	Yes. Marine survival has declined in many Sockeye Salmon populations in southern BC.
Are conditions for the source population deteriorating?[+]	Yes. Reduced marine survival as well as loss of spawning habitat.
Is the Canadian population considered to be a sink?[+]	N/A
Is rescue from outside populations likely?	No.

Data Sensitive Species

Is this a data sensitive species? No.

Status History

COSEWIC: Designated Endangered in an emergency assessment on 20 October 2002. Status re-examined and confirmed in May 2003. Status re-examined in an emergency reassessment on 20 April 2006 and confirmed Endangered. Status re-examined and confirmed in April 2016.

Status and Reasons for Designation:

Status: Endangered	**Alpha-numeric codes:** A2a; B2ab(ii,iii); D1
Reasons for designation: This population experienced a very large decline in the 1980s and 1990s because of low ocean survival and overfishing. Brood stock from Sakinaw Lake were maintained in a captive-breeding program that produced fry and smolts were 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.	

Applicability of Criteria

Criterion A: Meets Endangered A2a, the wild population declined by 100% in the last 3 generations
Criterion B: Meets Endangered B2ab(ii,iii) because the IAO is less than 500 km^2, the population exists in less than 5 locations, and there is a continuing decline in IAO and habitat quality.
Criterion C: Not applicable.
Criterion D: Meets endangered D1. The number of wild spawners is fewer than 250.
Criterion E (Quantitative Analysis): Not done

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect).

PREFACE

The status of the Sakinaw Lake Sockeye Salmon population was last documented in 2002 (COSEWIC 2003a) at which time it was designated as “endangered” but not listed by the Canadian government in 2005 although it committed to protect and rebuild the population (Withler *et al.* 2014). A draft recovery plan was developed by a recovery team (Sakinaw Sockeye Recovery Team 2005). While it was never officially adopted, it has been partially implemented. The goal of the recovery plan 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”. Included in the suggested recovery actions was implementation of a captive breeding program that would supplement the extant wild population. Unfortunately, the wild Sakinaw Lake Sockeye Salmon population became extirpated in the wild between 2006 and 2009, a period that saw annual returns of zero or one individual to the lake. Re-introduction of Sockeye Salmon from a captive breeding program established at Rosewall Creek hatchery on Vancouver Island began in 2002 from a founder population of 84 adult fish collected between 2002 and 2005. Returns from the captive breeding program first appeared in 2010 with 29 adults arriving in the lake. An average of 344 adults returned annually to the lake between 2011 and 2014. Production of hatchery fry appears adequate to maintain the population at this level. In-lake survival of naturally spawned fry remains low and subsequent marine survival of all smolts remains <1% constraining the ability of the population to rebuild. An important result has been that the diversity of the re-introduced Sockeye Salmon population, while reduced to some degree from the original population, maintains much of the historically observed heterozygosity.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2016)

Wildlife Species	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 either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada
Canadian Wildlife Service

Environnement et Changement climatique Canada
Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment and Climate Change Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

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Oncorhynchus nerka

Sakinaw population

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Sockeye Salmon, *Oncorhynchus nerka* Walbaum 1792, is in the order Salmoniformes, family Salmonidae, and is one of seven Canadian species in the genus *Oncorhynchus*, of which five are referred to as Pacific salmon and two as trout (Smith and Stearley 1989, Stearley and Smith 1993). The scientific name *Oncorhynchus nerka* derives from the Greek roots onchos (hook) and rynchos (snout), and nerka, a Russian common name for the species (Hart 1973). The name Sockeye, a corruption of the Coast Salish word sukkai (Hart 1973), is the most frequently used common name for the species. Other common names are red salmon (Alaska), blueback salmon (Columbia River), nerka and krasnaya ryba (Russia), and benizake and benimasu (Japan) (Burgner 1991). The French common name is saumon rouge. Common names “kokanee” or “little redfish”, among others, apply when non-anadromous (Scott and Crossman 1973).

Morphological Description

Sockeye Salmon can be distinguished from other species of the family Salmonidae by the 13 to 19 rays in the anal fin that are common to all Pacific salmon, and from other Pacific salmon species by the 28 to 40 long, slender, closely spaced gill rakers on the first arch, the relatively few pyloric caeca (45-115), and the fine speckling on the back (Hart 1973, Mecklenburg *et al.* 2002). Juvenile Sockeye have a slender, elongate body with elliptical or oval parr marks that extend little if at all below the lateral line. Adult Sockeye have a slender, streamlined, silvery body with faint blue-green specking on the back with silver sides fading to white below. During maturation, they undergo a distinctive transformation of external colour and body shape; the head becomes pale green while the body changes to a dull, brownish red becoming a brilliant scarlet in some populations. Males develop enlarged teeth and a hooked jaw and humped back, while females largely retain their marine body shape. Sockeye Salmon can reach a total length of 84 cm and weigh up to 7 kg, but their spawning size varies with age of maturity; both age of maturity and size at age vary widely among populations (Foerster 1968). Sakinaw Sockeye average about 2 kg in weight (Murray and Wood 2002). Precocious males (“jacks”), which spend only one winter at sea, are common in some populations (Burgner 1991). Kokanee typically mature at a smaller size and may lack brilliant colouration because they feed on small freshwater zooplankton throughout their life. Kokanee are known to occur in Ruby Lake, a tributary of Sakinaw Lake. Detailed descriptions of Sockeye Salmon can be found in Foerster (1968), Hart (1973), Burgner (1991), and Gustafson *et al.* (1997).

Population Spatial Structure and Variability

Like most salmon, Sockeye Salmon exist as reproductively isolated populations; however, they are discrete at a much smaller geographical scale than most other salmon (Wood 1995). This is because juvenile Sockeye Salmon typically rear in nursery lakes, which by their nature are discontinuous and geographically isolated, and often very different in physical and biotic characteristics (e.g., temperature and water flow regimes, nutrients, light penetration and primary productivity, competitors and predators, parasites and diseases, and factors that challenge anadromous migration). Reproductive isolation among Sockeye Salmon populations inhabiting different lake environments promotes the evolution of unique adaptations to the local freshwater environment. Consequently, Sockeye populations can differ considerably in life history traits and phenotypic characters (reviewed by Foerster 1968, Burgner 1991).

Evidence for Sakinaw Sockeye Salmon reproductive isolation:

Several surveys of genetic variation in allozymes (Wood *et al.* 1994), microsatellite DNA (Nelson *et al.* 2003, Withler, unpubl. data) and mitochondrial DNA (Murray and Wood 2002, Wood unpubl. data) demonstrate significant reproductive isolation between Sakinaw sockeye and other anadromous Sockeye populations in the region (Figure 1). Pairwise-F_{ST} statistics (measure of genetic differentiation among populations) based on comparisons of allele frequencies at 10 microsatellite DNA loci between Sakinaw Lake Sockeye and the nearest other Sockeye populations range from 0.06 (Koeye Lake, Statistical Area 9) to 0.13 (Heydon Lake, Statistical Area 13 and Nimpkish River (Woss Lake) in Statistical Area 12) (Table 1, above diagonal; some of these lakes are shown in Figure 1). These values (0.06 – 0.13) are large relative to those observed in other salmonid species over comparable distances and suggest that successful reproduction following immigration into Sakinaw Lake from other populations has been very rare. A more recent survey based on 14 microsatellite DNA loci shows allele frequencies between Sakinaw Lake and neighbouring lakes ranging from 0.03 (Village Bay) to 0.18 (Heydon) for a 1988 sample from Sakinaw and 0.04 (Village Bay) to 0.19 (Heydon) for samples from the re-introduced population in Sakinaw Lake (2011-2013) reinforcing the earlier findings of significant reproductive isolation (Table 2).

With one exception, pairwise-F_{ST} statistics based on comparisons of mitochondrial DNA haplotype frequencies (Table 1, below diagonal) range from 0.33 (Atnarko river system, Area 8) to 0.60 (Heydon Lake). The exception is Kimsquit Lake which is indistinguishable using mitochondrial DNA (F_{ST}=0.0, Table 1); however, a very large difference in allele frequency (16% versus 66%) at the PGM-1 locus, and smaller differences at two other allozyme loci (Wood *et al.* 1994), together with the microsatellite DNA differences in Table 1 (F_{ST} =0.09) indicate that this is a coincidental result of random genetic drift.

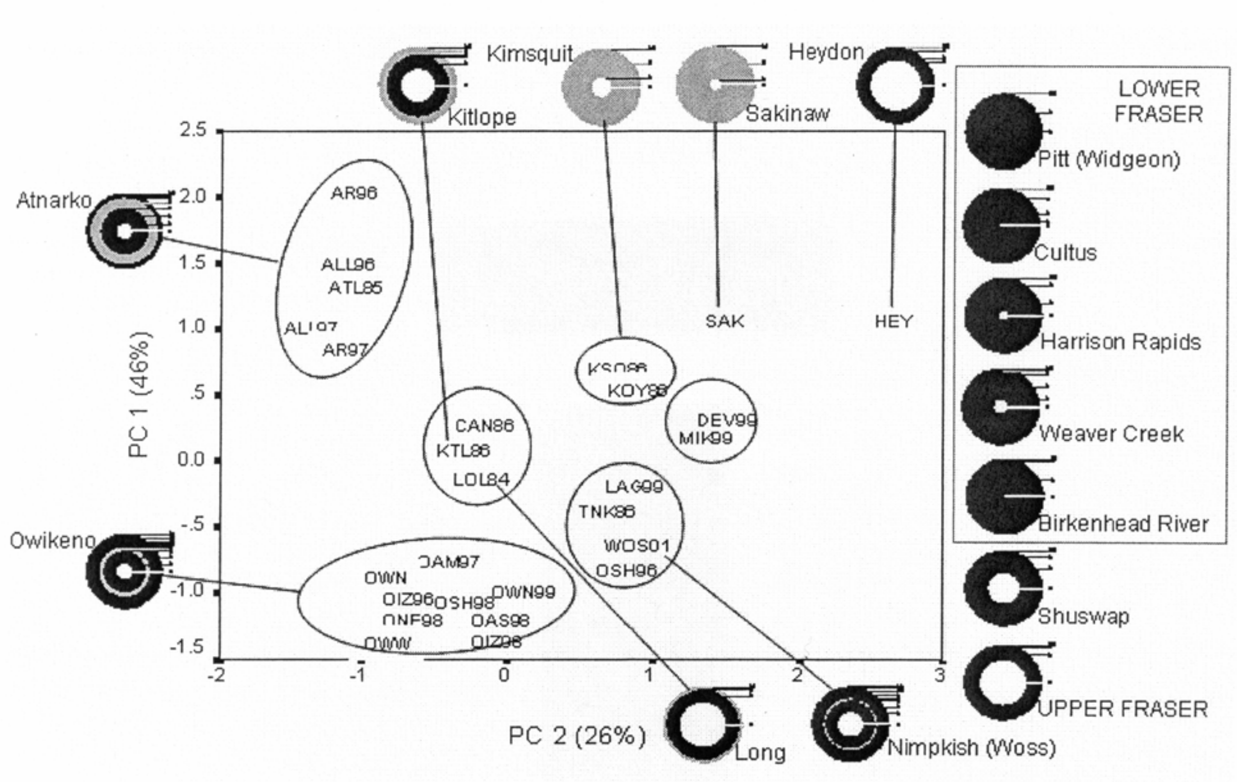

Figure 1. Principal components analysis of Cavalli-Sforza and Edwards' genetic distance between central coast Sockeye populations based on differentiation at 10 microsatellite DNA loci (from Nelson *et al.* 2003). Pie diagrams indicate relative frequencies of mitochondrial DNA haplotypes (haplotype #1 is shown as white, haplotype#5 as grey, all others as black). Fraser River populations are included for comparison because they were the source of attempted transplants to Sakinaw Lake (from Murray and Wood 2002).

Table 1. Pairwise Fst statistics for mitochondrial DNA (mtDNA; below diagonal, from Murray and Wood 2002) and microsatellite DNA (mSatDNA; above diagonal, from Nelson *et al.* 2003).

Populations	Sample Size		Population Number																				
No. Name	mtDNA	mSatDNA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1 Upper Fraser	158		0																				
2 Shuswap	19		.06	0																			
3 Birkenhead R.	25		.36	.39	0																		
4 Weaver Cr.	23		.25	.04	.45	0																	
5 Harrison Rapids	25		.22	.07	.18	.10	0																
6 Cultus	25		.36	.24	.48	.15	.25	0															
7 Pitt (Widgeon)	13		.53	040	.84	.20	.43	.52	0														
8 Sakinaw	27	113	.51	.56	.79	.55	.61	.60	.86	0	.13	.13	.08	.09	.06	.12	.09	.11	.10	.13	.11	.10	.09
9 Heydon	24	34	.10	.11	.60	.22	.35	.30	.60	.60	0	.14	.11	.12	.13	.17	.15	.15	.09	.16	.11	.11	.12

Populations	Sample Size		Population Number																				
No. Name	mtDNA	mSatDNA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
10 Nimpkish	24	50	.17	.03	.47	.04	.18	.23	.32	.47	.11	0	.06	.03	.08	.10	.11	.11	.08	.11	.04	.10	.10
11 Long	25	51	-.01	.09	.42	.28	.24	.36	.65	.56	.11	.18	0	.04	.06	.08	.06	.07	.05	.10	.05	.08	.08
12 Owikeno	59	104	.20	.05	.38	.03	.14	.20	.25	.38	.16	.02	.20	0	.06	.08	.09	.06	.05	.06	.04	.09	.09
13 Koeye		80	-	-	-	-	-	-	-	-	-	-	-	-	0	.09	.09	.07	.07	.10	.07	.08	.08
14 Atnarko R.	79	52	.26	.09	.44	.06	.19	.25	.22	.33	.21	.04	.26	.04	.00	0	.15	.11	.08	.09	.08	.12	.11
15 Kimsquit	13	62	.41	.39	.72	.42	.49	.48	.81	.00	.43	.31	.39	.27	.24	-	0	.15	.08	.12	.07	.12	.14
16 Tankeeah		78	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	.06	.12	.12	.11	.10
17 Lagoon		50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	.09	.07	.08	.09
18 Canoona		79	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	.08	.14	.15
19 Kitlope	15	41	.02	.04	.36	.18	.15	.27	.59	.45	.13	.10	-.02	.11	.16	-	.25	-	-	-	0	.10	.11
20 Mikado		62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	.00
21 Devon		100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

Table 2. Pairwise F_{st} statistics for 14 microsatellite DNA loci from Sockeye Salmon populations in southern and central British Columbia (R. Withler, unpubl data, 2015). West coast of Vancouver Island (WCVI) and east coast of Vancouver Island (ECVI).

Populations		South Coast				WCVI		ECVI		Fraser							
No.	Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	**Sakinaw Lake 1988**	**-**	**0.178**	**0.110**	**0.026**	**0.194**	**0.169**	**0.137**	**0.140**	**0.128**	**0.082**	**0.063**	**0.230**	**0.177**	**0.101**	**0.114**	**0.095**
1	**Sakinaw Lake2011-13**		**0.190**	**0.118**	**0.041**	**0.210**	**0.187**	**0.149**	**0.152**	**0.143**	**0.094**	**0.075**	**0.250**	**0.202**	**0.111**	**0.126**	**0.108**
2	Heydon Lake		-	0.132	0.163	0.191	0.245	0.138	0.134	0.165	0.132	0.113	0.220	0.198	0.092	0.117	0.110
3	Phillips River			-	0.103	0.194	0.172	0.114	0.112	0.090	0.070	0.076	0.236	0.153	0.079	0.094	0.081
4	Village Bay				-	0.200	0.144	0.105	0.108	0.120	0.071	0.056	0.226	0.163	0.085	0.098	0.080
5	Quatse Lake					-	0.254	0.198	0.195	0.206	0.164	0.158	0.295	0.219	0.162	0.188	0.149
6	Schoen Lake						-	0.147	0.158	0.198	0.146	0.153	0.340	0.238	0.151	0.195	0.175
7	Nimpkish Lake							-	0.003	0.140	0.102	0.091	0.228	0.176	0.088	0.113	0.106
8	Woss Lake								-	0.145	0.105	0.091	0.226	0.176	0.093	0.115	0.109
9	Bowron Lake									-	0.053	0.079	0.245	0.121	0.084	0.079	0.075
10	Lower Shuswap River										-	0.044	0.198	0.105	0.048	0.060	0.053
11	Pitt River											-	0.150	0.123	0.031	0.049	0.043
12	Widgeon Slough (Pitt R)												-	0.268	0.176	0.169	0.161
13	Cultus Lake													-	0.127	0.110	0.128
14	Harrison River														-	0.038	0.033
15	Weaver Creek															-	0.044
16	Birkenhead River																-

Evidence for local adaptation:

Sakinaw Lake and Village Bay (Quadra Island) represent the only two lake type Sockeye Salmon populations within the Strait of Georgia outside the Fraser River drainage. Sakinaw Sockeye are distinct from other Sockeye populations in the Pacific Northwest (data summarized by Gustafson *et al.* 1997, Nelson *et al.* 2003, Beacham *et al.* 2006) in terms of their early and protracted river-entry timing and extended lake residence prior to spawning. Small adult size results in both low fecundity and small egg size. Smolts are large and generally emigrate from the lake at one year of age. Large size at smolting and an unusual incidence of age 2+ smolts occur despite large size at age 1+. These characteristics are described further in the **BIOLOGY** section.

Local adaptation accounts for the widespread failure of attempts to transplant Sockeye Salmon runs from one lake system to another (Withler 1982, Wood 1995, Gustafson *et al.* 1997, Withler *et al.* 2000) or of restoring wild salmon populations in modified habitat (Williams 1987). Mitochondrial DNA data reported by Murray and Wood (2002, Table 1) provide compelling evidence that all five attempts (each year from 1902-1906) to transplant Sockeye fry to Sakinaw Lake from various locations in the lower Fraser River and from Shuswap Lake have failed. Only two mitochondrial DNA haplotypes (distinct maternal lineages) were found in adult Sockeye spawning in Sakinaw Lake in 1988, 2000, and 2001. These are designated haplotype #5 and haplotype #1. Haplotype #5 was predominant in Sakinaw Lake Sockeye at a frequency of 88% (±12% 19 times out of 20). But haplotype #5 was absent in samples from the Fraser River, including samples from all of the original donor lake systems. Except for haplotype #1, none of the haplotypes observed in the donor lake systems (#1, 2, 3, 4 and 6) were observed in Sakinaw Lake. Haplotype #1 is almost ubiquitous throughout the whole Asian and North American range.

To support the hypothesis that transplanted Sockeye may have survived in Sakinaw Lake, it would be necessary to demonstrate that the mitochondrial DNA samples are not representative, and that more extensive sampling would change these conclusions; or that haplotype composition has changed such that the Fraser River donor populations once had a very high proportion of fish carrying haplotype #5 and that these have died out; or that only a minority of transplanted fish (those carrying haplotype #1) survived in Sakinaw Lake. Because the haplotypes differ only in a few redundant nucleotides (third base pairs), they are almost certainly not expressed phenotypically and are considered “invisible” (neutral) to natural selection. Such postulated changes in haplotype composition could only occur by chance (genetic drift) and would be extremely unlikely given the sample size of introduced fish (380,000 fry over five years). These results suggest that recovering the Sakinaw Lake Sockeye population using transplants would be unsuccessful.

Designatable Units

Virtually all extant populations of Sockeye Salmon in Canada, southeast Alaska, and northern Washington State were established subsequent to the last glaciation which began 60000-70000 years ago and reached its greatest extent 18000–23000 years ago (Wood *et al.* 2008). Based on geological evidence and the geographical distribution of fish assemblages, McPhail and Lindsey (1970) concluded that Pacific salmon persisted during the last glaciation in isolated refuges in the Bering Sea region (Beringia) and south of the Cordilleran ice sheet in the Columbia River region (Cascadia). Patterns of allozyme variation in Canadian Sockeye populations also suggest that Sockeye Salmon persisted in at least one other isolated refuge along the coast of British Columbia (Wood *et al.* 1994). However, attempts to transplant fish from various populations to rebuild or recover depleted Sockeye Salmon populations within the Fraser River and Sakinaw Lake have generally been unsuccessful (Aro 1979, Wood 1995, Gustafson *et al.* 1997, Withler *et al.* 2000), supporting the genetic uniqueness of the Sakinaw population.

Sakinaw Sockeye Salmon are considered a designatable unit following COSEWIC guidelines. Protein electrophoresis and molecular DNA analyses indicate that Sakinaw Sockeye are substantially reproductively isolated from other Sockeye populations and thus meet the discreteness criterion. Their distinctive life history characteristics (early river-entry timing, protracted adult run timing, extended lake residence prior to spawning, small adult body size, lower fecundity and large smolt size) support their evolutionary significance. The evidence for very restricted gene flow between Sakinaw Sockeye and other populations, and the distance to the nearest extant Sockeye population both confirm that there is virtually no possibility of natural rescue from neighbouring Sockeye populations. All previous attempts to transplant Sockeye to Sakinaw Lake have almost certainly failed. Consequently, re-establishing a Sockeye run to Sakinaw Lake if the re-introduced population were to become extinct is highly improbable.

Special Significance

Sockeye Salmon are economically the most important species of Pacific salmon, contributing to commercial, recreational, and Aboriginal catches along the Pacific coast of North America. The number of extant populations has declined in the southern parts of the species' range. Currently, populations of North American Sockeye Salmon are considered endangered in three locations: two in Canada (Sakinaw Lake and Cultus Lake, BC; COSEWIC 2003a,b) and one in the United States (Snake River, Idaho; NOAA 2014). The Sakinaw Lake population is one of only two anadromous lake-type Sockeye Salmon populations situated in the 200-km length of the Strait of Georgia (the other is Village Bay Lake on Quadra Island, 100 km away at the extreme northern end of the strait). The conservation of Sakinaw Sockeye is a high priority for the Sechelt First Nation because these fish return to reproduce within Sechelt traditional territory. Sockeye Salmon may also play a significant role in maintaining the productivity of the Sakinaw Lake ecosystem, by importing marine-derived nutrients. The juveniles contribute to the complexity of the lake's food web, consuming invertebrates and serving as prey for native fish, birds and mammals. Returning adults are consumed by many species, including river otters, bears and parasitized by lamprey, and the carcasses provide food for bald eagles and other species. Therefore, Sakinaw Sockeye has a significant role in the ecology of the Sakinaw Lake ecosystem.

DISTRIBUTION

Global and Canadian Range

Sakinaw Sockeye Salmon reproduce only in Sakinaw Lake, situated on the Sechelt Peninsula in the Strait of Georgia, BC (Figure 2). They are endemic to Canada and share marine migration corridors and foraging habitat in the North Pacific Ocean with many other Sockeye Salmon populations.

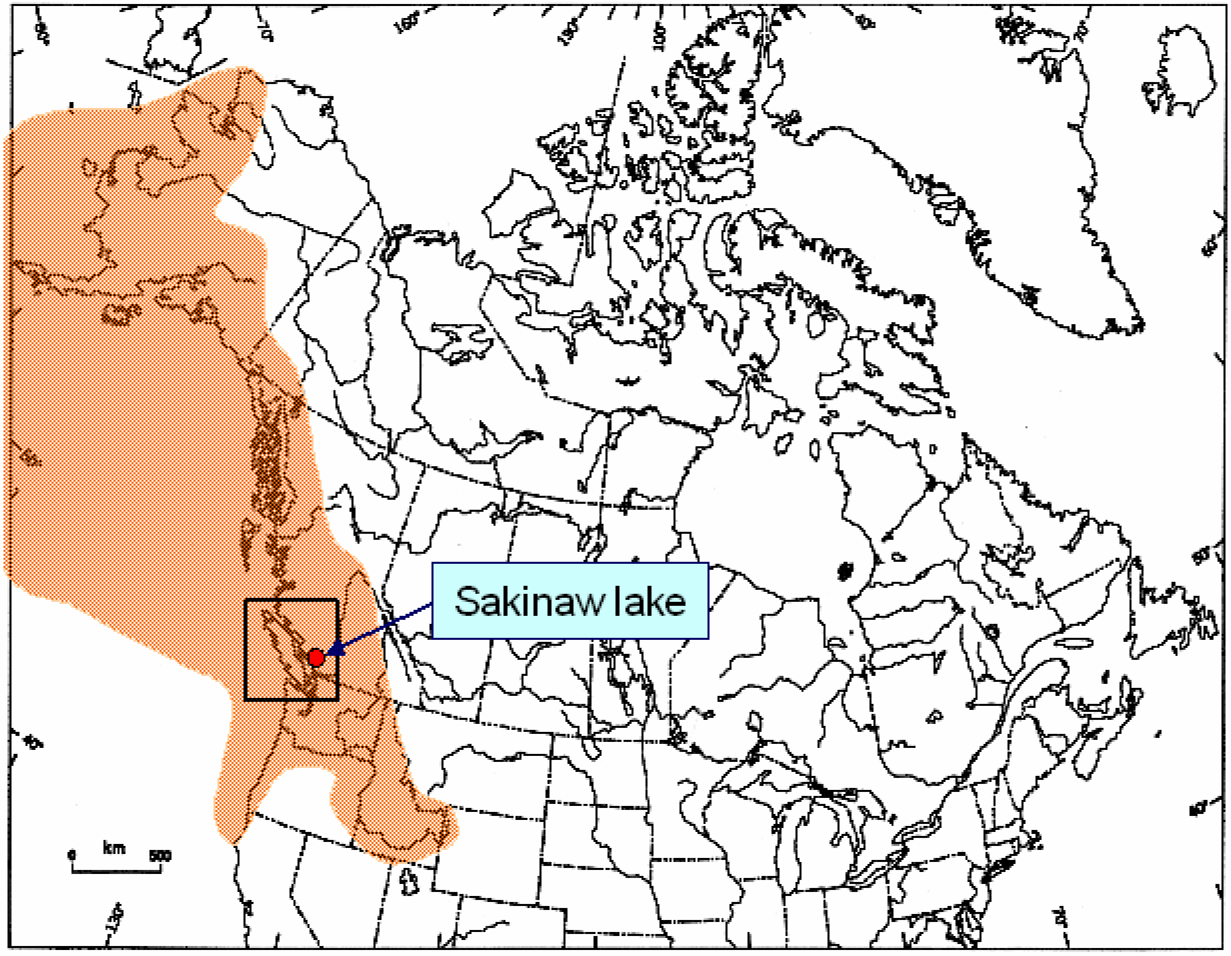

Figure 2. Natural range of Sockeye Salmon and Kokanee within North America (highlighted area, after Wood 1995).

Extent of Occurrence and Area of Occupancy

Sakinaw Sockeye like most Sockeye populations in the northeast Pacific Ocean migrate into the offshore undertaking an extensive counter-clockwise route prior to returning to their natal site to spawn and die (Burgner 1991). Recent tagging results confirmed that most fish moved directly northward after leaving the lake exiting the Strait of Georgia through Johnstone and Queen Charlotte straits (Wood *et al.* 2011). A small number of tagged smolts also migrated south through the Strait of Juan de Fuca. The extent of occurrence of Sakinaw Sockeye Salmon readily exceeds 20000 km^2 within the Pacific Ocean (Figure 2).

Sakinaw Sockeye have been seen spawning on as many as 5 beaches in the lake (Figure 3). However, recent spawning has been confined to only one beach, Shanon's Beach, in recent years. Assuming one spawning beach exists in one COSEWIC 2km x 2km grid, the IAO was historically 20 km^2 while it is currently 4 km^2.

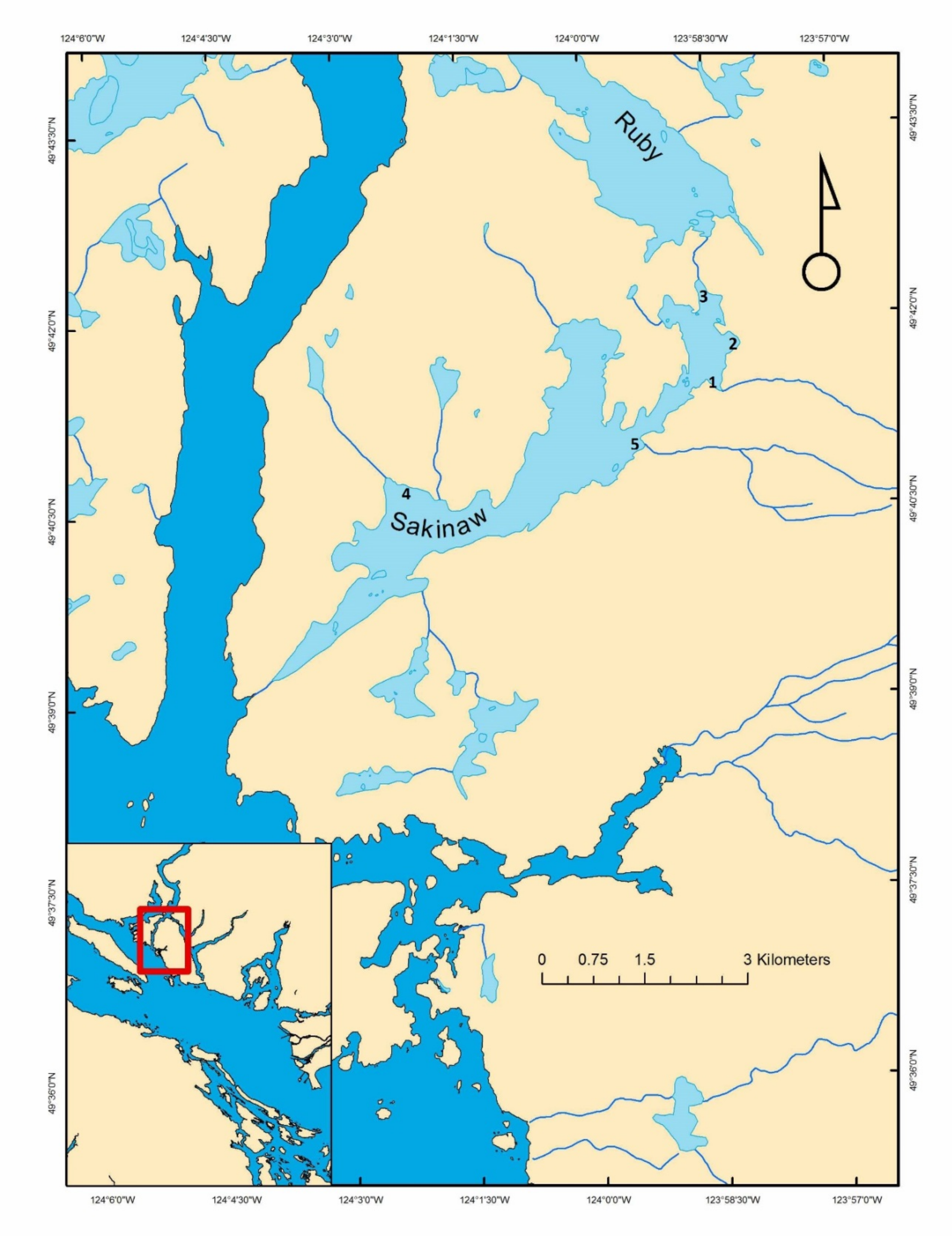

Figure 3. Sakinaw Lake, its tributaries and spawning beaches. Beach 1 (Sharon's Creek); Beach 2 (Haskins Creek); Beach 3 (Ruby Creek Bay); Beach 4 (Kokomo Creek Bay) and Beach 5 (Prospectors) (reproduced from DFO 2015).

HABITAT

Habitat Requirements

Sakinaw Sockeye have the same general habitat requirements as Sockeye Salmon in other populations (described by Foerster 1968, Burgner 1991). Sakinaw Sockeye require suitable spawning and rearing habitat within Sakinaw Lake to reproduce, foraging habitat in the North Pacific Ocean to attain adult size and unobstructed passage between them. Seaward migrating smolts must pass through the Georgia and Johnstone or Juan de Fuca Straits to reach the North Pacific Ocean where they spend two summers before returning to Sakinaw Lake by the same route. In the ocean, Sockeye Salmon typically inhabit cool (2-7ºC) surface waters (less than 15 m) and those from BC generally remain north of 48ºN latitude and east of 160ºW longitude (French *et al.* 1976). Their survival is affected by conditions in all these habitats.

Limnology of Sakinaw Lake

Sakinaw Lake has a surface area of only 6.9 km^2 and a perimeter of 35 km (Shortreed *et al.* 2003). It has two distinct basins separated at Beach 1 (Figure 3). The lower basin is the largest with a maximum depth of 140 m and a mean depth of 43 m. The upper basin is small and shallow with a maximum depth of only 40 m. Both basins are clear with a mean euphotic depth of just over 15 m (Shortreed *et al.* 2003). The overall drainage basin is only 64 km^2 but includes a number of small streams and lakes of which Ruby Lake is the largest with a maximum depth of 112 m.

Chemical, temperature and salinity conditions are unusual because Sakinaw Lake is meromictic with a 30 m freshwater layer overlying warm, anoxic salt water (Northcote and Johnson 1964); this prevents seasonal mixing and results in strong thermal stratification (Hutchinson 1957, Walker and Likens 1975). In summer, the epilimnion extends to 7 m depth and becomes too warm for Sockeye, but between 7 m and 30 m there is cool, well-oxygenated habitat that is rich in zooplankton and very suitable for rearing juvenile Sockeye (Shortreed *et al.* 2003). Overall primary productivity in Sakinaw Lake is higher than in other coastal BC lakes but lower than in most lakes of the Fraser River system including Cultus Lake (Shortreed *et al.* 2003). Total dissolved solid content ranges from 113 to 140‰. Temperature, salinity and conductivity all increase markedly with depth between 30 and 60 m. Temperature increases from 5°C to a maximum of 9°C at 60 m. Salinity continues to increase slightly with depth attaining a maximum value slightly over 11‰. A strong smell of hydrogen sulphide is evident in water samples from below 30 m, and samples from below 60 m may froth when brought to the surface. There is no evidence of seawater intrusion into the upper basin.

Spawning Habitat in Sakinaw Lake

Sakinaw Sockeye spawn almost entirely on beaches within the lake itself. A survey of the lakeshore carried out in 1979 revealed that only a small portion of the shoreline was suitable for beach spawning. No large spawning sites were found in the lower (main) basin and subsequent investigation there has focused on two small spawning areas. Spawning on all beaches was restricted to depths between 0.25 and 25 m with the greatest density of nests (redds) occurring between 3 and 10 m. All major beach spawning areas occurred near creeks or other obvious sources of groundwater. Evidence of habitat degradation was found at all spawning beaches littered with forest debris from the 1952 flooding of the lake and aquatic plants to a depth of 3 m at Beach 5 (Prospectors). Most spawning Sockeye were observed in the upper basin of the lake; of these, almost all (95%) were observed within the area that would have been most affected by a foreshore development proposal at beaches 1 and 2 (Figure 3). Recent surveys of the spawning beaches indicate that only beach 1 (Sharon's) continues to be in regular use (Sakinaw Sockeye Recovery Team 2013).

Habitat Trends

The most serious habitat degradation occurred prior to the diver survey in 1979 and was caused by logging debris and siltation. However, degradation has continued (Murray and Wood 2002). Dive surveys in 1999 and 2000 indicate that the Sockeye were using only 15% of the area of Beach 1 (900 versus 6,000 m^2). Beach 2 was no longer being used, and the suitable habitat there is estimated at about 25% of that available in 1979 (1500 versus 6000 m^2).

A restoration project of the spawning habitat on Haskins Beach (Beach 2) was conducted in 2000. After defining the areas with ground water upwelling an artificial beach was built using drain rock. The ground water upwelling successfully cleared the new gravel of silt but Sockeye spawners have only used Beach 1 in subsequent years (Murray and Wood 2002). Nevertheless, there has been ongoing restoration work on the spawning beaches since (Sakinaw Sockeye Recovery Team 2013).

Ocean growth and survival of Pacific salmon can be affected by periodic, warm water events (El Niño) in local waters, and by changes in ocean conditions in the North Pacific Ocean (e.g., Francis 1993; Beamish *et al.* 1997, Mueter *et al.* 2002a,b). McKinnell *et al.* (2011) provide evidence supporting an oceanic regime shift in 1989 that has led to reduced survival for Fraser River Sockeye and likely Sakinaw Sockeye as well.

BIOLOGY

The literature on Sockeye Salmon biology is extensive but a number of useful compendia exist including Foerster (1968), Burgner (1991), and Gustafson *et al.* (1997). The bulk of this section relies on these reports.

Life History Forms

Sockeye Salmon are anadromous and primarily spawn in rivers, though in some populations such as Sakinaw, spawning occurs in the lakes where juveniles rear. However, non-anadromous forms of the species also occur, maturing, spawning and dying in fresh water without entering the ocean. These forms are called Kokanee when they are genetically distinct from anadromous Sockeye, or “residual Sockeye” when they are the (mostly male) progeny of anadromous Sockeye. A few non-anadromous males have been found in Sakinaw Lake, but it is not known if they are residual Sockeye or Kokanee. Kokanee are relatively abundant in Ruby Lake and emigration of juveniles from Ruby into Sakinaw Lake is possible.

Life Cycle and Reproduction

Sockeye Salmon enter Sakinaw Lake throughout the summer from June to September with peak migration ranging from 20 July to 17 August over 40 years. Spawning occurs in the fall peaking in late November, with mean start and end times ranging from 20 October to 11 December. The behaviour of returning early, forgoing feeding opportunity in the ocean, and holding in the natal lake for three or four months before spawning is atypical of Sockeye Salmon but it is not uncommon in coastal lakes, apparently an adaptation to prevailing temperature regimes (Hodgson and Quinn 2002).

Sockeye Salmon have a high fecundity (2,000 - 5,200) and small egg size (5.3-6.6 mm in diameter) relative to other salmon species of the same size (Burgner 1991). Adult size and fecundity in the Sakinaw Lake population is at the lower end of the range for Sockeye Salmon (see Murray and Wood 2002, Gustafson *et al.* 1997). Sakinaw Sockeye may have evolved the size and return timing in response to Sakinaw Lake’s unique location and hydrology with short migration and access only during specific water flow conditions.

Sakinaw Lake Sockeye Salmon rely on incubation habitat within the nursery lake, typically along the shoreline in areas of upwelling water near alluvial fans. Choice of incubation habitat affects the availability of dissolved oxygen and the thermal regime (hence development rate) offspring experience during incubation, as well as exposure to predation and access to the nursery lake. Experiments have confirmed that both the timing of spawning and fry orientation behaviour (rheotaxis) at emergence exist as genetic adaptations to local conditions in Sockeye Salmon (Raleigh 1967; Brannon 1967, 1972, 1987).

Most anadromous Sakinaw Sockeye mature and return to spawn at age 4 (end of their fourth year of life) after spending two winters at sea, and have a four-year generation time. Age composition, by brood year, averages 3% age 3, 87% age 4, and 10% age 5. Despite their large size at smolting, Sakinaw Lake Sockeye are small at maturity compared with other Sockeye populations in Canada and the Pacific Northwest likely due to the short ocean residence (Gustafson *et al.* 1997).

Nutrition and Growth

Throughout the species' range, Sockeye Salmon fry typically emerge free swimming at 25-32 mm. Initially feeding near the lake shoreline, they subsequently shift to the deeper waters of the limnetic zone. Juvenile Sockeye are visual predators, feeding primarily on Copepods (*Cyclops, Epischura, and Diaptomus*), cladocerans (*Bosmina, Daphnia, and Diaphanosoma*), and insect larvae (Burgner 1991). Growth is influenced by food supply, water temperature, stratification and the length of the growing season, lake turbidity and migratory movements to avoid predation (Goodlad *et al.* 1974, Burgner 1991). Food availability also depends greatly on the density of juvenile Sockeye (Johnson 1961) and other limnetic fish, especially Threespine Sticklebacks (*Gasterosteus aculeatus*) (O'Neill and Hyatt 1987), Peamouth Chub (*Mylocheilus caurinus*) and sympatric populations of Kokanee (Wood *et al.* 1999). Faster growth rates can increase the survival of Sockeye Salmon during lake residence and subsequently through increased smolt size (Ricker 1962, Koenings and Burkett 1987, Henderson and Cass 1991).

Sakinaw Sockeye smolts are larger (100-150 mm) than those produced in most other nursery lakes (<100 mm) yet similar to those from Lake Washington, a very productive nursery lake for Sockeye Salmon (Doble and Eggers 1978, Burgner 1991). Comparison of scales from adult fish reveal that freshwater growth in Sakinaw Lake exceeds that for all other Sockeye populations in BC. Most juvenile Sockeye remain in Sakinaw Lake for only one winter (as free-swimming fish) before migrating to sea at age 1+. Based on the aging convention used by salmon biologists these fish are actually well into their second year of life when they enter the ocean. About 3% remain for two winters becoming even larger smolts. The age at which salmon smoltify is influenced primarily by growth rate but size thresholds for smolting are heritable (e.g., Thorpe *et al.* 1982) varying as adaptations among populations. Smolts from coastal populations are typically smaller and younger (implying a lower smolt size threshold) than interior lakes of comparable productivity making Sakinaw Sockeye atypical of coastal populations.

Physiology and Adaptability

The overall productivity of North American Sockeye Salmon populations and their subsequent perpetuation appears to be determined largely by conditions in the marine environment (Peterman and Dorner 2011). Welch *et al.* (1998) analysed 40 years of survey data on the distribution of Sockeye Salmon in the North Pacific Ocean noting that the catches were constrained to depths of less than 10 m and generally surface temperatures of less than 10ºC and virtually none were observed above 15ºC. The implication of these constraints is that under conditions of ongoing and future ocean warming Sockeye must adapt their behaviour to: “develop the ability to migrate into the Bering Sea (and return); begin to vertically migrate to stay below the thermocline for much of the day, migrating into surface waters to opportunistically forage for short periods of time; or incur the energetic or other penalties associated with thermal environments that they now strongly avoid” (Welch *et al.* 1998). Given the strong surface orientation of Sockeye Salmon and other salmonids, ocean warming may be anticipated to negatively impact future productivity and viability of the species especially near the southern extent of the range including Sakinaw Lake Sockeye.

As with many other species, attempts were made to transplant or re-establish many populations of Sockeye Salmon in the late 1800s and early 1900s. Despite numerous stocking attempts, establishment of self-perpetuating Sockeye Salmon runs have been documented only in three locations: 1) Lake Washington (Royal and Seymour 1940, Kolb 1971), 2) Frazer Lake, Kodiak Island (Blackett 1979), and 3) Upper Adams River in the Fraser River system (Williams 1987). Successful, documented transplants have all involved donor populations originating less than 100 km from the transplant site (Wood 1995).

Dispersal and Migration

Smolt migration out of Sakinaw Lake begins during early April and extends to mid-June, peaking in early May. The migration period was similar during four years of smolt enumeration (1994-1997, Bates and August 1997) with slight shifts in peak migration, which were perhaps affected by changes in lake discharge, temperature and weather. In a recent study of outmigration of Pacific Ocean Salmon Tracking (POST) tagged Sockeye smolts from Sakinaw Lake, Wood *et al.* (2011) determined that the majority of the smolts moved northward at speeds of 17-22 km/day after an initial acclimation of 7-14 days near the mouth of the lake passing out of the Strait of Georgia through Johnstone Strait while a small proportion exited via the Strait of Juan de Fuca. It was estimated that they left the release site at a rate of 30 percent/day.

Adult Sakinaw Sockeye are known to arrive in Johnstone Strait as early as 28 June based on a 1975 study of catch composition using scale pattern analysis (Henry 1961, Argue 1975). Fraser River stock composition sampling by the Pacific Salmon Commission found one Sakinaw Sockeye in southern Queen Charlotte Strait (Statistical Area 12) on July 12 in 2010. Tagging experiments indicate that Fraser River Sockeye Salmon migrate from the western end of Johnstone Strait to Texada Island (Statistical Area 16) in 7 to 14 days (Verhoeven and Davidoff 1962). The only tagging data available for adult Sakinaw Sockeye is for a single fish released on 10 August 1925 in Deepwater Bay (Statistical Area 13) and recovered eight days later in Sakinaw Creek (Williamson 1927). These limited data are consistent with more extensive observations of the timing of arrival at Sakinaw Lake. During 34 years of visual enumeration at the fishway (commencing in late June) the mean date of first arrival was 7 July and mean date of the last recorded arrival was 29 August. The mean date of peak migration was 30 July and the mean seasonal duration of the run was 53 days (range 33 to 88 days). Low water flow and high water temperature can impact subsequent migration into Sakinaw Lake.

Interspecific Interactions

Potential predators of juvenile Sockeye Salmon in or near Sakinaw Lake include Cutthroat Trout (*O. clarki*), juvenile Coho Salmon (*O. kisutch*) and Chinook Salmon (*O. tshawytscha*), Prickly Sculpin (*Cottus asper*) and Lampreys (*Lampetra tridentata and L. ayresi*). Parasitic gill copepods have been found on smolts. The main bird predators include the Common Loon (*Gavia immer*), Red-necked Grebe (*Podiceps grisegena*), Common Merganser (*Mergus merganser*), Belted Kingfisher (*Megaceryle alcyon*), Osprey (*Pandion haliaetus*), Bald Eagle (*Haliaeetus leucocephalus*) and various gulls (*Larus spp.*). Small populations of Coho and Chum (*O. keta*) salmon also occur in Sakinaw Lake and may compete with Sakinaw Sockeye for spawning habitat. In nearshore and open ocean environments, predation by fish, birds, and marine mammals, and competition for food resources with other fish species affects growth and survival of Sockeye.

Mammalian predators of adults likely include River Otters (*Lontra canadensis*), Harbour Seals (*Phoca vitulina*), Killer Whales (*Orca orcensis*), American Mink (*Mustela vison*) and Black Bears (*Ursus americanus*). Harbour Seals and River Otters are common near the lake outlet eating both smolts and adults within the small Sakinaw estuary and nearby Agamemnon Channel. About 10-15% of adult Sockeye passing through the fishway between 1957 and 1987 bore lamprey scars. Christensen and Trites (2011) summarized recent information on predators of Fraser River Sockeye most of which would likely also consume Sakinaw Sockeye. No single predator species was identified that would account for recent declines in Sockeye survival rates.

Predation on migrating salmon is typically depensatory (e.g., Wood 1987) so its role in limiting smolt-to-adult survival could have increased as the abundance of Sakinaw Sockeye declined. However, this would depend on trends in abundance of alternative prey including other salmonids. An aquaculture site established at Daniel Point (just south of Sakinaw Lake) during the early 1990s may also have attracted mammalian predators and increased their abundance in proximity to fish migrating to and from Sakinaw Lake.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Anecdotal reports of escapement date back to 1933 but routine assessments began in 1947 and are reported in the DFO annual spawning escapement surveys (BC 16s) and are available in the Salmon Escapement Data System (SEDS) database (Murray and Wood 2002). There is some concern regarding the consistency in methodology over the years. The methods for deriving the reported escapement estimates were not standardized but usually involved counting the salmon by species as they passed over the dam into the lake and relating the counts to timing of observations to get a total population estimate (Murray and Wood 2002). Counts are affected by tide and water levels, weather conditions, timing of surveys, and changes in staff.

Adult Sockeye Salmon returning to Sakinaw Lake have most often been enumerated as they pass upstream through the fishway at the lake outlet from mid-June through mid-September (Table 3). The fishway was monitored consistently until 1989. From 1990 to 1999 a series of beach-based observations occurred but are considered unrepresentative of true abundance because spawning occurred at depths of more than 9 m. From 1999 to 2002, a series of dive surveys were conducted in November and December on the main spawning beaches to enumerate abundance of spawners and the associated number of nests (redds) (Murray and Wood 2002). Since 2002, adult returns were estimated from the fishway exclusively, using a continuously recording Avigilon motion-detecting video system, minus any fish collected for hatchery broodstock (Withler *et al.* 2014).

Table 3. Estimated abundance of Sakinaw Lake Sockeye Salmon from 1947 to 2014 and releases of fry (juveniles in the lake) and smolts (juveniles leaving the lake) following the initiation of a captive breeding program to supplement the population.

Brood Year	BC 16 Escapement[c]	Clipped Fry Released Arranged by Brood Year	Unclipped Fry Released Arranged by Brood Year	Clipped Smolts Released Arranged by Brood Year	Unclipped Smolts Released Arranged by Brood Year	Released Fry to Smolt Survival by Brood Year
1947	3,500					
1948	4,600					
1949	3,931					
1950	2,473					
1951	3,450					
1952	6,222					
1953	1,131					
1954	4,143					
1955	5,079					
1956	2,150					
1957	4,300					
1958	4,250					
1959	13,000					
1960	4,500					
1961	750					
1962	3,500					
1963	7,500					
1964	3,500					
1965	750					
1966	3,500					
1967	6,000					
1968	14,000					
1969	1,200					
1970	5,000					
1971	8,000					
1972	4,500					
1973	1,500					
1974	6,000					
1975	16,000					
1976	6,000					
1977	1,200					
1978	4,000					
1979	11,000					
1980	2,800					

Brood Year	BC 16 Escapement[c]	Clipped Fry Released Arranged by Brood Year	Unclipped Fry Released Arranged by Brood Year	Clipped Smolts Released Arranged by Brood Year	Unclipped Smolts Released Arranged by Brood Year	Released Fry to Smolt Survival by Brood Year
1981	3,000					
1982	3,400					
1983	1,600					
1984	1,115					
1985	2,400					
1986	5,400					
1987	4,200					
1988	2,500					
1989	1,000					
1990	1,200					
1991	500					
1992	1000					
1993	250					
1994	250					
1995	[a]					
1996	222					
1997	3[b]					
1998	1[b]					
1999	14					
2000	112	14,981	0			
2001	87	31,922	0	8,080	4,334	
2002	78	2,784	0	39	103	25.3%
2003	3	0	0	2	11	1.4%
2004	99	25,927	0	8,357	2,926	
2005	28	95,465	0	3,739	272	32.2%
2006	1	84,626	0	11,982	182	3.9%
2007	0	420,781	0	62,370	222	14.2%
2008	0	0	726,376	404	69,538	14.8%
2009	1	0	329,360	0	32,892	9.6%
2010	29	0	1,373,822	0	162,877	10.0%
2011	555	963,328	0	224,575	27,960	11.9%
2012	243	856,205	0	121,468	4,435	23.3%
2013	143	320,416	0			14.2%
2014	464					

[a] Not assessed.

[b]Estimates considered unrepresentative (DFO 2015), not used in determination of trends in abundance.

[c]BC 16s are DFO reports of the annual escapement surveys in the brood year.

Manipulated Population

The following section deals with how Sakinaw Sockeye should be treated according to COSEWIC's Guidelines on Manipulated Populations. Guideline #1 requires that manipulated populations be clearly identified, if they are considered part of the wildlife species being assessed, and whether they are included in the application of quantitative criteria.

DFO established a recovery team and developed a conservation strategy for Sakinaw Sockeye following the 2002 COSEWIC status assessment of Endangered. The strategy included a captive-breeding program that used 84 wild Sakinaw Sockeye Salmon adults collected in 2002-2005 as the initial brood stock (DFO 2015). All subsequent breeding fish have either been captured in the lake or raised to maturity in the hatchery. In summary, the captive-breeding program is a manipulated population established to preserve the species and therefore it should be considered part of the wildlife species (Guideline #2).

In most brood years (year of spawning, BYs), hatchery-reared fry were marked with an adipose fin clip prior to release into the lake. Smolts were examined for fin clips during emigration as were adults upon their return to the lake (Withler *et al.* 2104). However, hatchery-reared fry were not clipped during BYs 2008–2010. Clipping of hatchery fry resumed with the 2011 BY.

The Sakinaw Sockeye population became extirpated in the wild between 2006 and 2009, a four-year period in which one or zero adult Sockeye Salmon was observed entering the lake each year (Withler *et al.* 2014). For a semilparous species with a four-year generation time this means that no “wild” individuals have survived. The DU has been preserved by the captive-breeding program and is therefore considered to be extant.

Between 29 and 555 hatchery released fish returned to the lake from 2010-2014 (Table 3, DFO 2015). Of the 29 returns in 2010, 16 were captured for the captive-breeding program. It was not possible to tell if any of the remaining spawners in 2010 produced return spawners in 2014 because the hatchery releases in BY 2010 were unclipped. Thus, it is not possible at this time to determine if any second-generation fish have returned to the lake and if the manipulated population is having a net positive impact on the wildlife species. According to guideline #3, the returns in 2010-2014 should not be used in evaluating quantitative criteria.

Indices of Spawning Abundance

For Sockeye Salmon, the number of mature fish in the population is usually estimated as the number of spawning fish because they attain maturity and subsequently spawn and die in the same year. In most populations, this is roughly equivalent to the numbers that survive coastal fisheries and reach their natal spawning habitat (called the “spawning escapement”). SEDS estimates show no obvious trend between 1947 and 1987, fluctuating between 750 and 16,000, and averaging about 4,500 (Table 3). Since 1987, escapement estimates have decreased steadily (Figure 4). To some extent, enumeration effort and inconsistent methods affected the accuracy of the yearly estimates from 1989 through 1998, but the decline was dramatic (Table 3). More systematic dive surveys of the spawning grounds conducted in 1999 through 2002 yielded estimates from 14 (23 redds) to 112 spawners (60 redds).

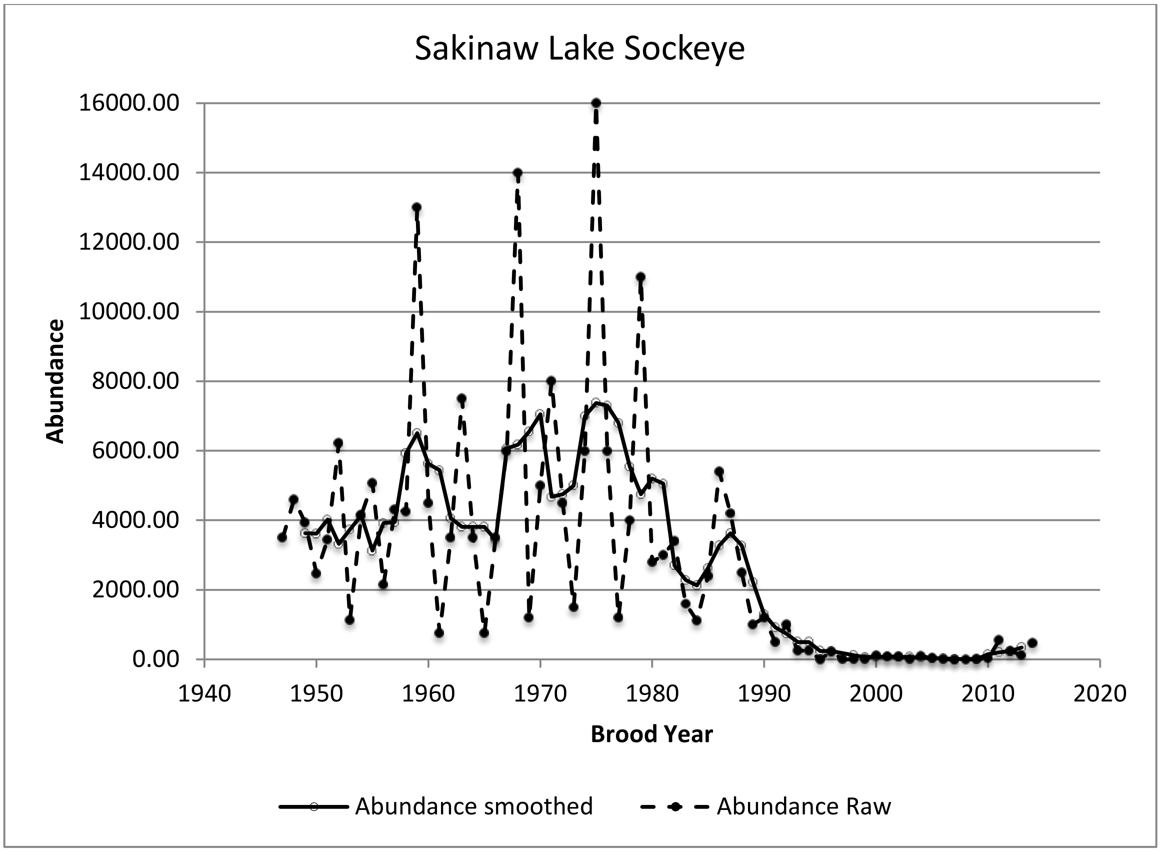

Figure 4. Annual abundance estimates for adult Sakinaw Lake Sockeye from 1947 to 2014 and for a 4-year running average smoothed escapement estimate. Abundance estimates from 2010-2014 reflect returns of captively bred fish.

In 2002, Sockeye were enumerated both at the fishway and by dive survey, allowing a direct comparison; the fence count was 78 whereas the diver count on the spawning beaches was only 44. These results suggest that dive surveys may underestimate true abundance, which seems surprising in view of the excellent viewing conditions, and possibility for inadvertently counting the same fish again on a subsequent survey. Alternatively, it may indicate that Sockeye experience significant mortality after entering Sakinaw Lake, which seems plausible because they enter the lake several months before spawning. In the lake they are vulnerable to predation, especially by a non-anadromous parasitic lamprey (probably *L. tridentata*). All spawning Sockeye captured as broodstock in 2002 bore lamprey scars although none had fresh wounds.

In 2003, only 3 returning spawners were counted into the lake and the following two years saw 99 and 28, respectively. From 2006 to 2009, either 0 or 1 Sockeye returned to the lake and the population was assumed to be extirpated in the wild. Subsequently, maturing adults returned to the lake from the ocean to spawn from 2010 through 2014 (range 29 to 555) as a result of fry releases into the lake (Table 3) from the captive breeding program (Withler *et al.* 2014).

Fluctuations and Trends

Annual counts of spawning fish should represent all mature fish in the population in each year, but they often fluctuate widely because of year-to-year variations in brood year (parental) abundance and survival. An additional consideration with Sockeye Salmon populations is the phenomenon of cyclic (run) dominance wherein there occur very strong returns of spawners every 4 years in some southern BC populations followed by much weaker returns in intervening years. Such a pattern is apparent in the escapement estimates from 1950 through the early 1980s (Figure 4). A 4-year running mean time series of escapement was calculated in order to smooth this cyclic dominance, a practice common for other sockeye populations (Grant *et al.* 2011). Figure 5 presents the 4-year mean escapement over the past period of 3 generations (based on the argument above). It clearly shows that the number of mature individuals declined by 100% during this time period; a statistical analysis is not required.

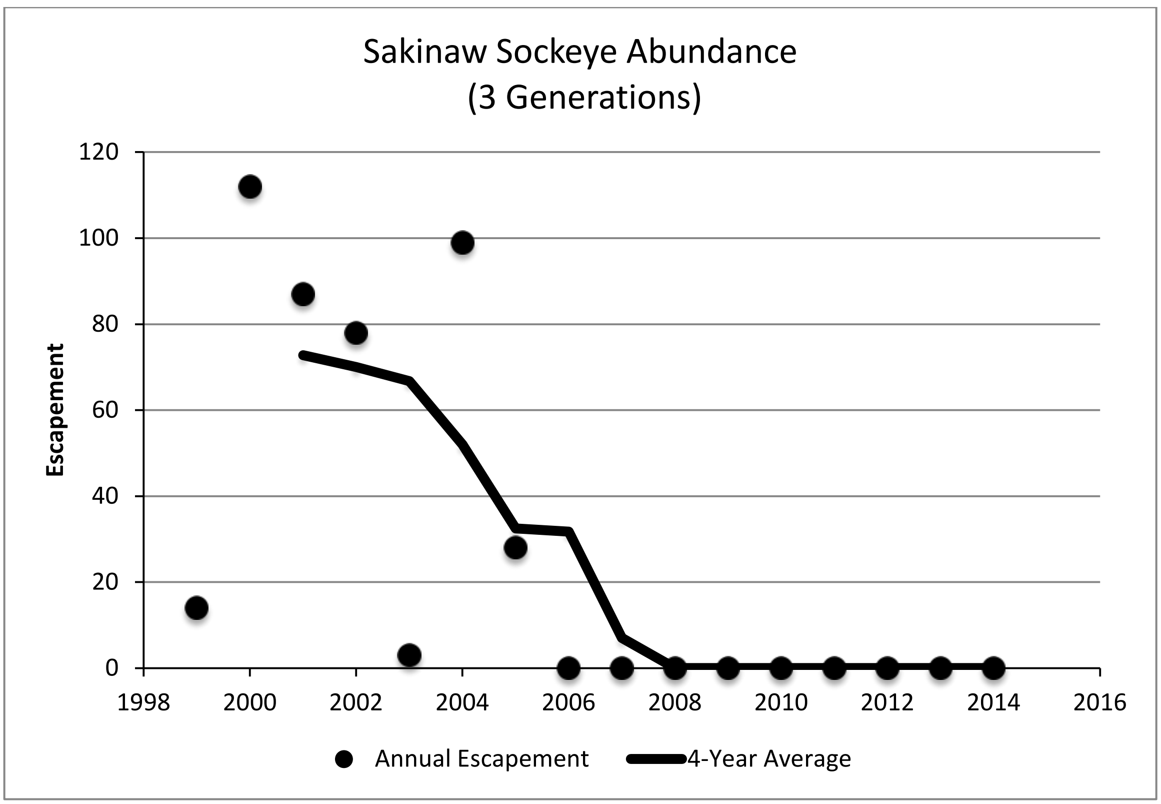

Figure 5. Trend in adult Sakinaw Sockeye abundance for the last three generations from 1999 to 2014.

Indices of Juvenile Abundance

Smolts were enumerated by mark-recapture experiments at the outlet of Sakinaw Lake from 1994 to 1997. The total smolt outmigration in those years was estimated at 15,880, 12,760, 2,500 and 5,200, respectively, based on a trap efficiency of 3 to 5% (Bates and August 1997). If smolt-to-adult survival rate was 4.5%, an average value for other Sockeye populations with large smolts (Forester 1968), the corresponding total adult returns before fishing mortality would have been 715, 574, 113, and 232 adults in 1996, to 1999, respectively. Reported escapements in these years were considerably lower (1 to 222), probably because of underestimation by surveys, and losses to both fishing mortality and in-lake predation. However, even ignoring the estimates of spawning escapement and assuming that marine survival had been favourable and fishing mortality negligible, the smolt abundances indicate that adult abundance must have declined by an order of magnitude since the more reliable counts in the 1980s.

Since the introduction of the captive breeding program an increasing number of fry have been released into Sakinaw Lake since the 2005 BY from the Rosewall Creek hatchery. Survival rate to smolting has averaged 15% (range 4-32%) but subsequent marine survival to returning adult spawners has remained very poor at <1% (Withler *et al.* 2014). Indications are that about 1.7 million smolts would need to be released annually to rebuild the population to 5,000 adults given current survival rates.

Rescue Effect

Rescue of Sakinaw Sockeye from other Sockeye populations is not possible. Sakinaw Sockeye are reproductively isolated from other populations based on protein electrophoresis and molecular DNA analyses. Their distinctive life history characteristics indicate that they are evolutionarily distinct from other Sockeye populations in North America. The very restricted gene flow between Sakinaw Sockeye and other populations (Table 1, 2), and the geographical distance to the nearest extant Sockeye population confirm that there is virtually no possibility of natural rescue from neighbouring Sockeye populations. All previous attempts to transplant Sockeye into Sakinaw Lake have almost certainly been unsuccessful (Withler *et al.* 2000). Consequently, re-establishing a Sockeye run to Sakinaw Lake if the re-introduced population were to become extinct would not be successful. A recently established captive breeding program is maintaining the population at a very low level relative to historical abundance.

THREATS AND LIMITING FACTORS

There are a variety of limiting factors and threats to the survival of Sakinaw Lake Sockeye, including those in the freshwater and marine environments from both natural and anthropogenic factors. Although not specific to Sakinaw Lake Sockeye, the Cohen Commission reports (Cohen 2012) summarize what is known about threats to Fraser River Sockeye Salmon that potentially could also affect Sakinaw Lake fish and some of these are included below.

Freshwater Habitat

Beach spawning habitat in Sakinaw Lake (particularly at Beach 1) is susceptible to landslides caused by rapid increase in stream flow and flooding, especially in winter when rain falls on snow. Mean annual precipitation ranges from 850 mm at lower elevations to 2,500 mm at higher elevations. Maximum precipitation occurs in winter as rain with less than 10% of total precipitation falling as snow at sea level, although this proportion increases significantly with elevation (see Murray and Wood 2002 and Shortreed *et al.* 2003 for detailed descriptions of climate and limnology).

Human activities or natural events that reduce groundwater upwelling or reduce substrate permeability by adding silt or wood debris near spawning sites could cause mortality during incubation by interfering with the delivery of oxygenated water and the removal of metabolic wastes. Beach spawning habitat has been degraded by the recreational boat launch and the cumulative effects of log debris following the flooding of the lake in 1952. The most serious habitat degradation was evident prior to the first diver survey in 1979, but impacts have continued. Dive surveys in 1999 and 2000 indicate that the Sockeye were using only 15% of the area of Beach 1, and that none were using Beach 2 where only 25% of the formerly suitable habitat appeared suitable (Murray and Wood 2002). Old spawning areas not presently used by Sockeye are covered with thick mud, organic debris and large logs.

Although Sakinaw Lake lies at an elevation of only 5 m, access to and from the lake can be difficult for Sockeye Salmon during periods of low water flow (COSEWIC 2002). 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. Low water flow and high water temperature can impact migration into Sakinaw Lake, and Sockeye Salmon enter the fishway only on the higher tides at night. The presence of predators, most notably River Otters, in or near the fishway can disrupt the spawning migration. When migration is disrupted, fish that return to the ocean cannot gain access until the following night because of the water level. Passage to the fishway was improved in 1995 by the installation of two large rock weirs in the creek below the dam to create large pools. The pools act as steps and offer some protection for the migrating Sockeye Salmon from illegal fishing but exposes them to predation. In addition, effort has been made to restructure the outflow so that it remains concentrated in a narrow channel to facilitate fish movement.

Natural Marine Factors

It is generally believed that most natural marine mortality is caused by predation, and physical (temperature, salinity, currents) and intrinsic biotic factors (genetic adaptation, nutrition, parasites and disease) affect vulnerability to predators (also see Cohen 2012, v. 2, Christensen and Trites 2011, Kent 2011). Marine predators include a wide range of species from diving birds, piscivorous fish, to pinnipeds and killer whales. There is some evidence from scarring and trawl catches to suggest that Sakinaw Sockeye may be especially vulnerable to parasitism by river lampreys (*Lampetra ayresii*) that are relatively abundant in Georgia Strait near Sakinaw Lake. In addition, there is evidence of lamprey parasitism of Sockeye fry and smolts in the Sakinaw Lake. Ocean growth and survival of all species of Pacific salmon can be affected by periodic warm water events (El Niño) in local waters, and by changes in ocean conditions in the North Pacific Ocean (e.g., Francis 1993; Mueter *et al.* 2002a,b, McKinnell *et al.* 2011). Given the reduced abundance of Sakinaw Sockeye depensatory predation may be significant in maintaining the population at the current low numbers.

Fisheries

Sakinaw Sockeye 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*). While terminal fishing has not occurred in recent years, reliable estimates of past terminal catch are available for only three years: 1947, 1952 and 1972. The terminal harvest rates in those years were estimated as 1.4, 14.0, and 23 to 29%, respectively (Murray and Wood 2002). Sockeye Salmon migrate back to Sakinaw Lake through Johnstone Strait (Figure 6). They share this migration corridor with other Sockeye Salmon populations including those returning to lakes in the vicinity of Johnstone Strait (Nimpkish, Heydon, Phillips and Village Bay lakes) 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. A higher diversion rate implies a higher fishing effort in fisheries that intercept Sakinaw Sockeye.

The overall intensity of mixed-stock fishing in Johnstone and Georgia straits generally increased until the late 1990s in response to high abundance and high diversion rates of Fraser River Sockeye Salmon through Johnstone Strait. Although fishing effort as measured by fishing days has declined, technology has increased the efficiency of seining. Gillnet fishing effort also increased in the 1980s. Murray and Wood (2002) provide a detailed description of the fishery. However, increased fishing effort in mixed-stock fisheries does not necessarily imply increased fishing mortality on small populations like Sakinaw Sockeye. Detailed information on run timing and migration routes past fisheries are required to reliably estimate population-specific harvest rates, and these data are seldom available for minor stocks. Fishing effort is regulated based on test-fishing indices of the abundance of large Fraser River Sockeye populations.

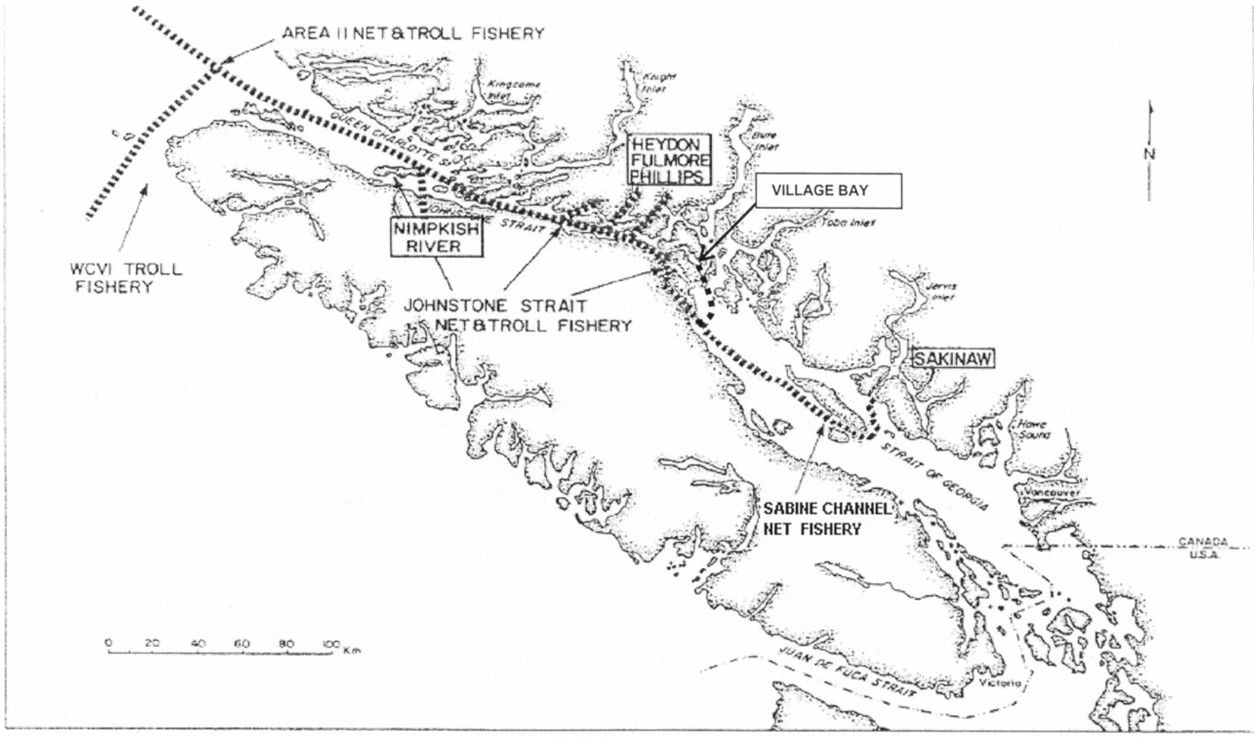

Figure 6. Primary route for adult migration (dotted lines) and location of fisheries for non-Fraser Sockeye populations (Nimpkish, Heydon, Fulmore, Phillips, Village Bay and Sakinaw). Sakinaw Sockeye are harvested primarily in the Johnstone Strait and Sabine Channel net fisheries (taken from Murray and Wood 2002).

The Pacific Salmon Commission (PSC) used scale analysis to estimate the contribution of Sakinaw Lake Sockeye to net fisheries in Johnstone and Georgia Straits in the 1975 fishing season. These estimates of catch composition imply that the total catch and exploitation rate of Sakinaw Sockeye in that year were 14,300 fish and 47%, respectively (Argue 1975). Comparable stock composition data for Sakinaw Lake Sockeye are not available for other years. However, Starr *et al.* (1984) concluded from run reconstruction analyses that total exploitation rates on Sakinaw Sockeye varied from 20 to 67%, averaging 41% between 1970 and 1982.

Murray and Wood (2002) inferred the minimum total exploitation rate on Sakinaw Lake Sockeye for the periods 1986-89 and 1992-94 using two methods. The first relied on assumptions about stock composition in Johnstone Strait fisheries and migration rate to Sakinaw Lake. Estimates of total harvest rate on early Stuart Sockeye in Johnstone Strait fisheries (and by extension, Sakinaw Lake Sockeye) ranged from 1 to 56% (average 21%) assuming a 7-d migration, and 1 to 97% (average 57%) assuming a 14-d migration. The second method reconstructed the probable catch of Sakinaw Lake Sockeye from PSC estimates of the weekly aggregate non-Fraser Sockeye catch. Of the non-Fraser populations, Nimpkish River Sockeye occur in two areas; Heydon, Fulmore and Phillips Lake Sockeye occur in three areas, whereas Sakinaw Lake Sockeye are present in all four fishing areas. Based on their contributions to these catches, exploitation rates on Sakinaw Sockeye averaged 49 to 57% (depending on assumption about migration rate) between 1986 and 1989, and 89 to 99% between 1993 and 1994.

Additional estimates of exploitation rate for Sakinaw Sockeye Salmon were developed by Folkes *et al.* (2006, unpublished data) for 2004 and 2005 using similar methodology and assumptions about the shape of the run timing curve and using daily fence counts and daily harvest rate data to reconstruct the run size. The 2004 exploitation rate was estimated at 15% and the 2005 rate at 4%. Following the extirpation of the population in the wild between 2006 and 2009 and returns of fish from the captive breeding program in 2010 and 2011, the Sakinaw Sockeye Recovery Team (2013) estimated the exploitation rate in 2010 at between 15 and 21% depending on the assumption around the smoothing of the daily harvest rates. The estimate for 2011 was 7% using the same methods. Inevitably, fishing mortality will continue to be a threat to any rebuilding of the Sakinaw Sockeye population despite the reductions in fisheries since 1998 aimed at protecting threatened populations of various salmonids.

Exposure to Fish Farms

Tagging of juvenile Sockeye Salmon from the Fraser River indicates that migration to the Pacific Ocean occurs primarily through Johnstone Strait exposing them to infestation by sea lice as they encounter fish farms in Johnstone Strait. The significance of this infection to juvenile survival remains unclear. Connors (2011) investigated the correlation between fish farm production and Fraser Sockeye survival and found no association of wild Sockeye Salmon survival and the number of sea lice on farmed fish, the incidence of disease in farmed fish, or the total number of farmed fish produced. Connors (2011) did note that the survival of Fraser Sockeye Salmon was reduced when farm fish production was high, sea surface temperature in the Pacific Ocean was reduced, and Pink Salmon abundance was high. Noakes (2011) similarly reported no direct effects of fish farm production on subsequent Fraser River Sockeye survival. However, Dill (2011) noted that due to the short time series of available data it cannot be concluded that there is no effect of the fish farms on Sockeye Salmon survival. A recent study provides some evidence that an increased incidence of sea lice on Sockeye has a direct impact on their feeding and competitive ability (Godwin *et al.* 2015). Consequently, exposure of Sakinaw Sockeye juveniles to fish farms must be viewed as a potential threat.

Species Introductions

Sockeye Salmon fry were transplanted into Sakinaw Lake each year from 1902 to 1906. The Sockeye fry were reared at the Fraser River Hatchery near New Westminster, which operated from 1884 to 1915. The donor stocks were the Harrison (Big Silver, Weaver Creek, Trout Lake, Harrison River Rapids sites), Pitt River (Upper and Lower) and Birkenhead rivers and Shuswap Lake (Scotch and Tappin creeks, Adams River). Approximately 380,000 fry were transplanted into Sakinaw Lake from the various donor stocks (Aro 1979). Genetic evidence indicates that these transplants were unsuccessful (Wood 1995).

The British Columbia Fish and Wildlife Branch attempted to augment the natural population of sea-run Cutthroat Trout in Sakinaw Lake by stocking 297,931 juvenile Cutthroat Trout (most over 10 g in weight) between 1965 and 1989. Lacustrine predators can limit Sockeye smolt production and Cutthroat Trout are known to be predators on young Sockeye at all times of the year (Foerster 1968). Thus, stocking Sakinaw Lake with Cutthroat Trout may have decreased the survival of juvenile Sockeye in Sakinaw Lake.

Number of Locations

The Sakinaw Sockeye Salmon population existed in this single location within Sakinaw Lake prior to its extirpation between 2006 and 2009. The captive breeding program that exists to maintain and rebuild the population is located at the hatchery at Rosewall Creek on Vancouver Island and is maintained by DFO. Re-introduced Sockeye Salmon began to spawn in Sakinaw Lake again in 2011 but the population is maintained by hatchery supplementation. A Sakinaw Lake Sockeye population now exists effectively in two locations. However, any disease outbreaks at the hatchery or other catastrophic events that destroy the captive brood population would likely render the Sakinaw Sockeye DU extinct.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Sakinaw Lake Sockeye are not protected within any park or marine protected area. Existing protections for Sakinaw Sockeye are similar to those for Interior Fraser Coho Salmon, summarized previously by Irvine (2002) and restated here as follows: Canada is a signatory to the international Convention on Biological Diversity that requires governments to develop legislation and policies to protect ecosystems and habitats and maintain viable species populations. The *Canada Oceans Act* (1996) directs DFO to manage Canada's marine resources to conserve biological diversity and natural habitats. The federal *Fisheries Act* has long required that proposed alterations to habitat be authorized by DFO. However, in BC, provincial and municipal governments also regulate many land and water use activities that can affect fish populations. For example, the provincial *Water Sustainability Act* governs the allocation of water, water licences, and the regulation of works in streams.

In 1998 DFO released its New Directions Policy for the Pacific region (DFO 1998). The first two principles in this policy state that conservation of Pacific salmon stocks is DFO's primary objective, to take precedence over other objectives in managing the resource, and that a precautionary approach to fisheries management will continue to be adopted. The New Directions Policy stimulated development of a Wild Salmon Policy (DFO 2005) to promote the long-term viability of Pacific salmon populations and their natural habitat. Reduced mixed-stock fishing effort in Johnstone Strait since 1998 is one consequence of DFO's renewed emphasis on conservation, consistent with the New Directions Policy. Following the listing by COSEWIC of Sakinaw Sockeye as Endangered in 2002 and subsequent non-listing under SARA, DFO developed the Sakinaw Sockeye Conservation Strategy (2008) to recover the population. Consistent with the strategy, the draft Integrated Fisheries Management Plan (IFMP 2015) provides for restrictions on fishery impacts on Sakinaw Sockeye. Sakinaw Lake Sockeye have a prolonged migration period commencing in Johnstone Strait in late May to July and arriving at the entrance to Sakinaw Lake in July and August. They are most vulnerable to harvest directed at Fraser River Sockeye stocks in July extending into mid-August. As a result, most fisheries that have potential to intercept Sakinaw Lake Sockeye are delayed prior to the last week of July to ensure a significant portion of the return has passed through major fisheries in Johnstone Strait (IFMP 2015). The plan provides for:

- Restrictions in First Nations Food, Social, and Ceremonial fisheries to gill net and troll only until July 25 in Johnstone Strait and until August 15 in the northern Strait of Georgia.
- Recreational fisheries in Queen Charlotte Strait, Johnstone Strait, and upper Strait of Georgia closed to Sockeye retention until July 25. The waters near the mouth of Sakinaw Creek in Area 16 closed to fishing all season. In addition, sockeye non-retention in Area 16 until August 15 at which time Sockeye retention opportunities are expected to be available in Sabine Channel.
- Commercial fisheries in Queen Charlotte Strait and Johnstone Strait closed until July 25 and in the upper Strait of Georgia (including Sabine Channel) until August 15.

In addition to harvest-related measures, efforts continue to improve the habitat (debris removal from spawning areas), and research into the impacts of predation (Seals, Otters and Lamprey) is ongoing. The captive brood program is continuing as insurance to reduce the possibility of extinction.

Non-Legal Status and Ranks

Sakinaw Sockeye is not listed by any other national or international organization.

Habitat Protection and Ownership

The perimeter of Sakinaw Lake is a mixture of Crown Land and Private Land holdings. Additionally the Sechelt First Nation has a Reserve at the outlet of the lake with a vested interest in preserving the habitat. The existing foreshore developments are a mixture of houses and cottages the majority of which have been in situ for 30 or more years. The Sakinaw Lake Heritage Investment group purchased the property at Haskins Beach that had been slated for development in the early 1980s to preserve the site which supported one of the main spawning locations for Sakinaw Lake Sockeye (G. McBain, DFO, pers. comm., 2015). Several Forest Licensees have tenures in the area including Terminal Forest Products Ltd., International Forest Products Ltd, Canadian Forest Products Ltd, and BC Timber Sales.

A moderate-sized human population resides for at least the summer on the shores of Sakinaw Lake. Portions of the lakeshore have been altered, including the riparian zone. The west side of the lake has seen limited development due to its topography, and riparian forests appear more intact (Sakinaw Sockeye Recovery Team 2005).

Development is ongoing within the watershed and will continue to create demands and challenges on water quality and quantity. A detailed water management plan for this area identifying water usage issues needs to be formulated. The lake's riparian and upland terrestrial habitats are protected through the *BC Forest and Range Act* on all Crown forestlands, and the Land Development Guidelines on lands falling within the Sunshine Coast Regional District (SCRD). However, this provides limited protection for lake foreshore in the Pender Harbour Area 'A' Official Community Plan (Sakinaw Sockeye Recovery Team 2005). The lake and its beaches are afforded additional protection, regardless of whether they are Crown or private lands, through the Federal *Fisheries Act*.

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