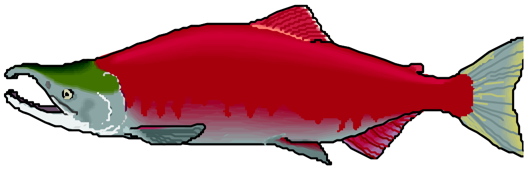


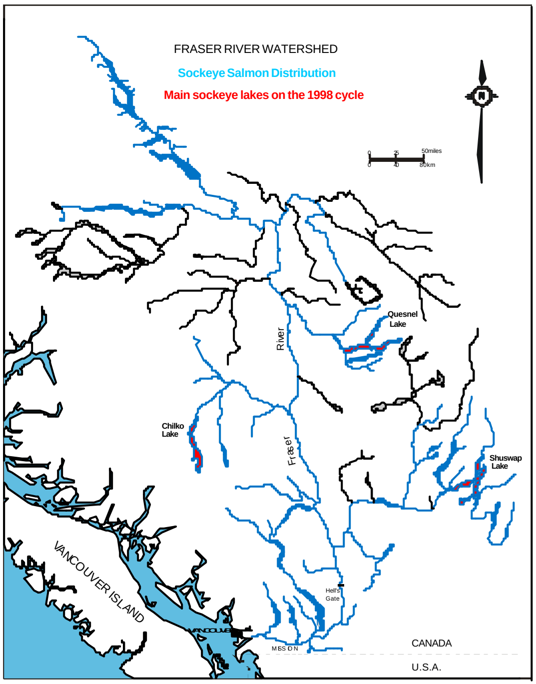
THE 1998 FRASER SOCKEYE CYCLE

Background

Fraser sockeye salmon (Oncorhynchus nerka) mainly mature and spawn at age 4. Most juveniles rear for about one year in a lake before migrating to sea. Over 150 individual populations can be identified by spawning location and migratory timing pattern. Of approximately 20 sockeye populations in the Fraser River watershed that are enumerated routinely, 8 exhibit persistent 4-year cycles with a predictable dominant-year cycle line every 4 years. The 1998 cycle or cycle line refers to the sequence of years 1998, 1994, 1990 ... 1902, etc. The term "dominant-year cycle line" refers to the sequence of years wherein the run size is persistently larger than the other cycle lines. Run size is persistently lowest on off-year cycle lines and intermediate on the subdominant cycle line.

Hypotheses to explain the cycles centre on identifying factors that impose higher mortality when abundance is low than when abundance is high (i.e. depensatory mortality). Various ecological hypotheses have been proposed that theorize predation during early sockeye freshwater development is depensatory. Other explanations centre on evidence for depensatory fishing mortality. Despite intensive investigations on the subject, scientists have failed to reach consensus on the causes of cycles in Fraser River sockeye.

Hudson Bay Company records prior to 1873 indicate that all the major Fraser River sockeye runs exhibited 4-year cycles, with the dominant cycle occurring on the 1901 (1997) cycle line throughout the watershed. Later documents of the British Columbia Department of Fisheries also confirm that spawning abundance to the upper Fraser River populations cycled in synchrony



between 1901 and 1913. Estimates of the number of spawners on the 1901 line up to 1913 (1897-1913) range from 5 million in 1909 to 13 million in 1901. The International Pacific Salmon Fishery Commission reported catches of 35 million in 1913 (Fig. 1).

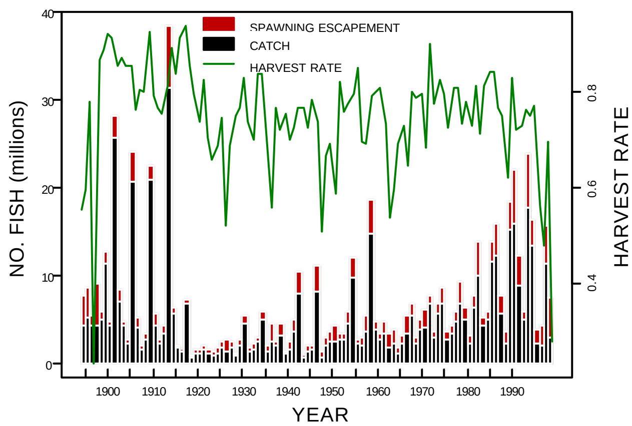


Figure 1: Catch, spawning escapement and harvest rate (1894-1998).

Owing to obstructions in the Fraser canyon at Hell's Gate most sockeye returning to the Fraser failed to reach the spawning grounds in 1913 and consequently the 1901 (1997) dominant cycle was lost as was the *synchrony in cycles. The rebuilding of runs in the years that followed eventually resulted in smaller differences in sockeye abundance among the four cycle lines. Individual runs rebuilt beginning in 1926 with large increases to the Adams River on the 1998 cycle line. Spawning stock size for other runs began to increase in the 1930s. Sustained increases in all runs, however, were only achieved following construction of fishways in the Fraser Canyon and a 5-year fishing closure on early and mid-season run timing groups during 1946-50.*

The 1998 cycle line rebuilt to be the most abundant cycle line until the 1990s, when the abundance of 1997 cycle line surpassed the abundance of the 1998 line. The rapid rebuilding of the 1998 cycle line that occurred between 1930 (5.5 million) and 1958 (19 million) was temporarily halted following high mortality of the 1958 year class. The run size in 1962 was only 3.5 million sockeye. The 1998 line since rebuilt to a maximum of 22 million sockeye in 1990. In 1994, the total sockeye return was estimated at 17 million. The estimated total returns in 1998 of 10.9 sockeye represent a 36% decline from returns in 1994.

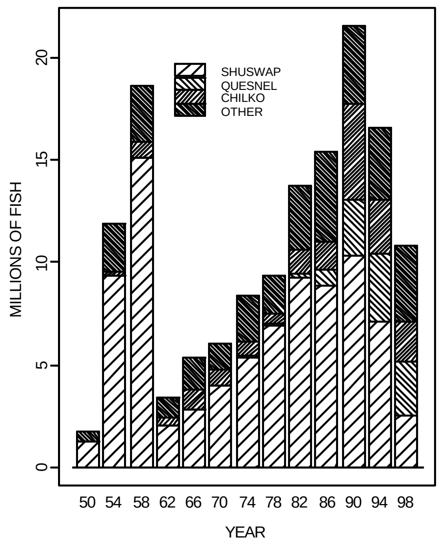


Figure 2: Run Size for the 1998 Cycle line (1954, 1958…1998).

Historically, the dominant Adams River (Shuswap Lake) run has been the single largest spawning population in the Fraser River watershed and the main contributor to the 1998 cycle line. Other important contributors to the 1998 cycle line are Chilko and Quesnel Lake sockeye. These two stocks have increased relative to the Shuswap Lake stock in recent years (Fig. 2). Major discrepancies in estimates of run size and low spawner abundance of Shuswap Lake sockeye in 1994 led to the formation of the Fraser River Sockeye Public Review Board. During the summer spawning migration in 1998, the potential for high mortality from record high water temperatures in the Fraser River prompted remedial in-season management action to reduce harvest rates and increase spawning escapement. By the end of the fishing season there was a discrepancy of 3.5 million fish between estimates of fish passage in the lower Fraser River at Mission and up-river estimates of catch-plus-spawning escapement. Despite a review of the possible causes of the discrepancy conducted jointly by Fisheries and Oceans Canada and the Pacific Salmon Commission, it is not known whether the apparent loss was due to natural causes brought on by the high water temperatures or other factors. Including the discrepancy, the run size in 1998 of 10.9 million sockeye was the lowest total abundance on the 1998 cycle since 1978. The estimated spawning escapement in 1998 of 4.4 million sockeye, however, was the second largest reported on the cycle and the third largest for all years (1938-98).

The Fishery

Fraser River sockeye have had profound social and ceremonial importance to aboriginal peoples. Following construction of the first cannery on the Fraser River in 1866, the commercial gillnet fishery developed rapidly. The amount of catch taken before the advent of the commercial fishery is unknown but presumably it was small compared with the commercial catch. Reconstructed estimates of commercial catches ranged from 35 to 50 million fish per year on the 1901 (1997) line before 1913. Estimates of catches on the 1902 (1998) cycle line ranged from 4 to 7 million fish per year.

As a result of habitat destruction, most notably the effects of the Hell's Gate slide, and overfishing, catches on the 1998 cycle line declined in one generation from 5.7 million sockeye in 1914 to 800,000 sockeye in 1918. Between 1918 and 1958 catches on the 1998 line gradually increased to 15 million sockeye.

Catches in 1962 dropped to less than 2 million sockeye but increased to 16 million in 1990. Catches in the two most recent cycle years (1994 and 1998) were 13 million and 3 million sockeye. In response to the extreme water temperatures in the Fraser River watershed in 1998, harvest rates were reduced to increase spawning escapement levels. The harvest rate on the 1998 cycle averaged 69 % between 1954 and 1998. The harvest rate was deliberately reduced in 1962, 1966 and 1970 to rebuild the 1998 cycle following the high mortality of the 1958 year class. The harvest rate of 28 % in 1998, based on a run size that includes the 3.5-million-fish discrepancy, was the lowest on record since 1946.

During 1937-84, the International Pacific Salmon Fishery Commission (IPSFC) was responsible for management of fisheries in a "Convention Area" that included Canadian and U.S. fisheries in southern B.C. and U.S. waters of Washington State. During that period catches from Convention Area fisheries were shared equally between Canada and the United States. With ratification of the Pacific Salmon Treaty in 1985, the Fraser River Panel under the auspices of the Pacific Salmon Commission has regulated management of Fraser sockeye fisheries. The Fraser River Panel consists of Canadian and U.S. representatives. Its purpose is to ensure spawning targets set by Canada, and international and domestic catch allocation goals are met. Following several years in the 1990s of managing Fraser sockeye fisheries in the absence of a Canada-U.S. agreement on catch sharing, a new long-term agreement was endorsed in 1999. The U.S. share phased in over the next few years will be fixed at 16.5 %. This compares with the average agreed share of 20.5 % between 1985 and 1996. Historically, the proportion harvested by the United States was much greater.

In 1987, Canada embarked on a stock rebuilding strategy designed to test production capacity limits mainly by increasing the number of natural (wild) spawners. Spawning channels were build in a limited scale by the IPSFC to supplement natural populations (i.e. Weaver channel) but the present rebuilding strategy is intended to increase spawning escapement by harvest management action rather than artificial enhancement.

Most of the catch is taken large mixed-stock ocean fisheries. Canadian commercial catches have mainly been taken in the troll fishery off the west coast of Vancouver Island, purse seine and gillnet fisheries in Johnstone and Juan de Fuca straits, and the gillnet fishery in the Fraser River. Smaller commercial fisheries also occurred in northern and central B.C. and within the Strait of Georgia. In 1998, the Canadian commercial catch was 2.2 million fish. The proportion of Canadian commercial catch by gear in 1998 was 32 % troll, 34 % purse seine and 34 % gillnet. Sockeye are harvested in First Nations food fisheries throughout the Fraser River watershed. The Canadian First Nations catch in 1998 was 844,000 sockeye. Sport catches are presently small but estimates have recently increased. In 1998, 18,000 sockeye were reported in the Canadian sport fishery. U.S. fisheries occur mainly in the net fisheries in Juan de Fuca Strait and southern approaches to the Fraser River located in U.S. waters. Some Fraser sockeye are also taken in south-eastern Alaska. The total U.S. catch in 1998 was 708,000 sockeye.

Stock status and future prospects

Fraser River sockeye have been very productive as measured by the number of adults produced from each spawner. An average of four adult recruits were produced per spawner for the Shuswap Lake stock on the 1998 cycle line since 1948. Productivity for that stock, however, has been highly variable, ranging from less than 1 to 8 recruits-per-spawner (Fig. 3). The high inter-annual variation results in pre-season run size forecasts that are very uncertain.

For most sockeye populations, there is little evidence of diminishing adult returns at the upper range of spawning stock sizes observed. This is true for Shuswap Lake sockeye (Fig. 4). For some stocks we have seen lower return rates in a few years of high spawning stock sizes. However, with high survival variability independent of the number of spawners, repeated high spawning levels are required to assess optimal stock sizes.

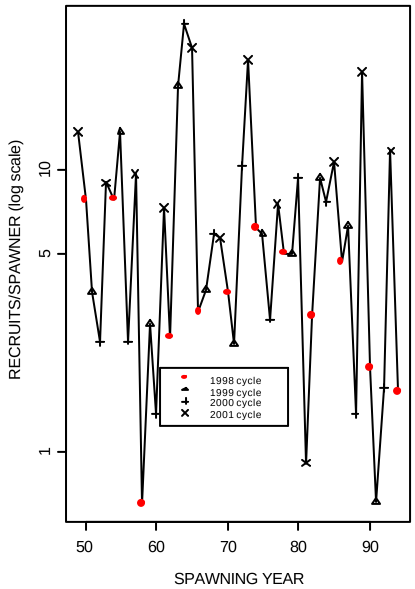


Figure 3: Adult recruits per spawner (Spawning years 1949-94)

The high spawner abundance in 1958 of 3.3 million sockeye resulted in only 1.1 million adult returns or 0.6 recruits-per-spawner. There is considerable controversy surrounding the significance of the low recruits-per-spawner for the 1958 brood. A fence was constructed at the outlet of the Adams River to prevent over-escapement in 1958. The effect of the fence reportedly resulted in a large number of lake spawners and unnaturally high egg mortality. Despite the potential for biases in the estimates of spawning escapement for Adams River sockeye in 1958, survival of the 1958 year class was low for other stocks as well. Whatever the cause of the low recruits-per-spawner for the 1958 brood, 1958 is a pivotal year in the relationship between the number of spawners and subsequent returns for Shuswap Lake sockeye (Fig. 4). Limnological studies of sockeye rearing lakes have also been used to estimate the spawning capacity of Shuswap, Quesnel and Chilko lakes. Those studies indicate the juvenile numbers do not increase beyond total spawning escapements of 1.4 million to Shuswap, 0.9 million to Quesnel and 0.5 million to Chilko lakes. It is important to note that these estimates are also subject to uncertainty as a result of estimation errors.

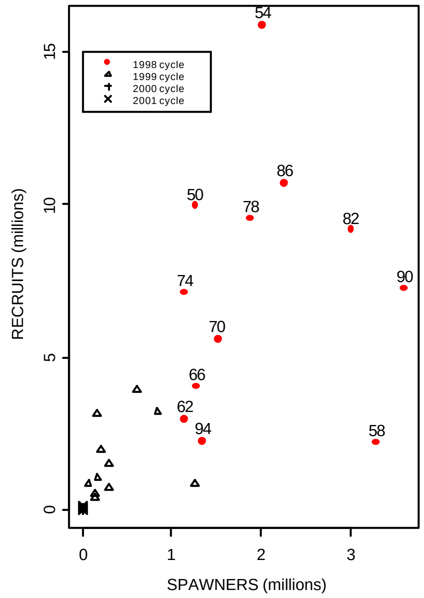


Figure 4: Spawner-Recruit relationship for Shuswap Lake Sockeye (Spawning years 1949-1994). Data labels indicate the years for the 1998 cycle line.

Trends in recruitment at any particular spawning stock size are not only affected by short-term inter-annual variations in survival but also by long-term climatic variations in productivity. The implications for long-term effects of global warming on sockeye production, for example, are difficult to predict but extreme inter-annual variation in environmental conditions recently have occurred. High river discharge rates that occurred in 1997 and 1999 as a result of heavy winter snow pack and the very low flow rates and high river temperatures brought on by drought conditions in 1998 have undoubtedly impacted future production. Water discharge in the lower Fraser River during the 1998 sockeye migration was near or below the 86 year minimum. Mean daily water temperatures at Hell's Gate were the highest on record for most days during the summer of 1998, frequently exceeding 20°C. In addition to immediate adult mortality from extreme environmental conditions, the potential physiological effect of environmental stress on future production as a result of low reproductive success and reduced egg viability have not been measured. To what extent recent extremes in freshwater passage conditions and low survival rates are the result of long-term climate change is not known.

Historically, economic yield from the 1998 cycle line has mainly come from the dominant line of the Shuswap Lake stock. The rapid rebuilding of Chilko and particularly the sub-dominant Quesnel Lake stock in recent years indicates larger economic returns on this cycle are likely. Additional gains on the 1998 cycle depend on the extent to which other runs can be rebuilt. The current lack of understanding of the processes that maintain cyclic patterns in Fraser sockeye is undoubtedly the single greatest obstacle to maximizing Fraser sockeye potential. Even under pessimistic scenarios, increases in yield should result from increases in spawning abundance to off-cycle runs. If strong dominant-year cycle lines act to suppress other cycle lines, then it might be advisable to limit the abundance of the 1998 cycle at an intermediate level to create greater biological opportunity for the off-year cycle lines. Certainly, there is no evidence to indicate the current cyclic pattern is optimal. For the Adams/Shuswap stock complex, the low cycle years (2000 and 2001 cycle lines) have persisted at low levels despite population growth on the dominant and sub-dominant cycles. Ultimately, the processes that perpetuate population cycles and prevailing climatic factors affecting survival will determine the rate that low runs can be rebuilt to maximize long-term socio-economic benefit from Fraser River sockeye.

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