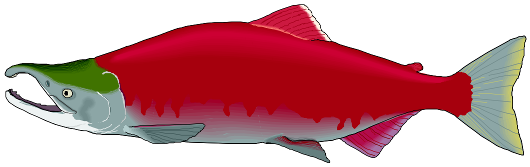
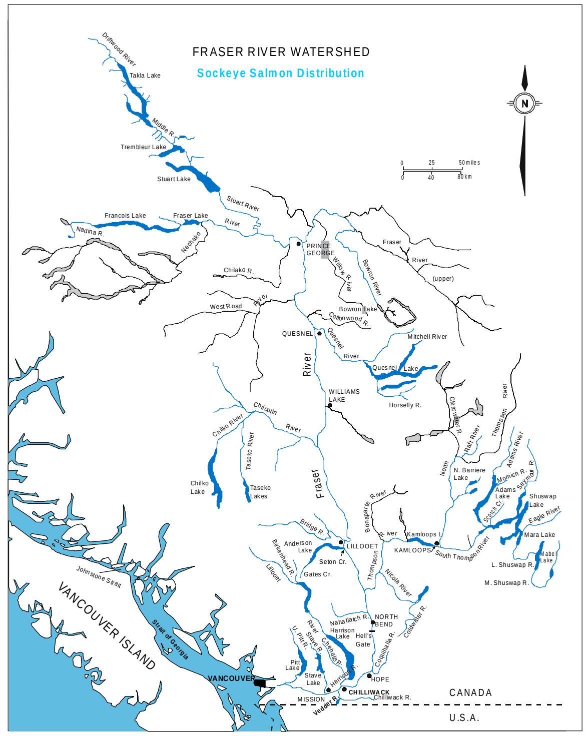
Fisheries and Oceans   Pêches et Océans
Pacific Region

DFO Science
Stock Status Report D6-01 (1998)



The 1997 Fraser Sockeye Cycle



Background

Cyclic fluctuations in abundance are characteristic of many fish populations with a single predominant reproductive age. Fraser sockeye mainly mature and spawn at age-four. Of approximately 20 sockeye populations in the Fraser River watershed that are counted routinely, eight exhibit persistent four-year cycles with a predictable dominant-year cycle line every four years. The 1997 cycle or cycle line refers to the sequence of years 1997, 1993, 1989...1901, 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.

The processes that maintain population cycles in Fraser sockeye are poorly understood. There is strong evidence that cycles are not merely echoes of past random catastrophic perturbations that persist due to the simple age structure of these populations. Hypotheses to explain cycles centre on identifying agents that impose higher mortality when abundance is low than when abundance is high (i.e. depensatory mortality). Various ecological hypotheses have been proposed that theorise predation during early sockeye freshwater development is depensatory. Other explanations for population cycles centre on evidence for depensatory fishing mortality.

Considerable evidence has been compiled to suggest that the 1901 dominant cycle line, destroyed by rock dumping during railroad construction at Hell's Gate in 1913-14, had persisted since the time of the first Hudson's Bay Company (1820) records and perhaps since the first reference to Fraser River sockeye (1793).

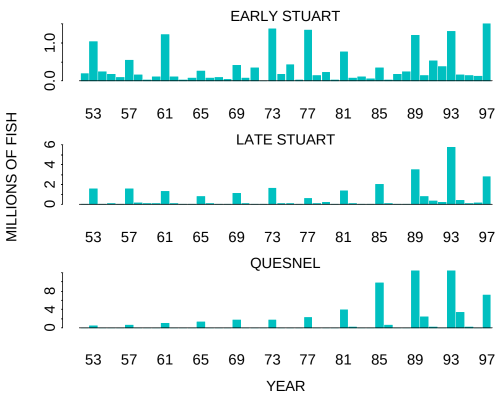
Hudson Bay Company records prior to 1873 indicate that all the major Fraser River sockeye runs exhibited four-year cycles, with the dominant cycle occurring in the same year. Later documents of the British Columbia Department of Fisheries also confirm that spawning abundance to the upper Fraser River 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 five million in 1909 to 13 million in 1901. The International Pacific Salmon Fishery Commission (1973) reported catches of 35 million in 1913. Dominant runs prior to 1913 may have been about 100 million sockeye.

Owing to obstructions in the Fraser canyon at Hell's Gate, most sockeye returning to the Fraser River failed to reach the spawning grounds in 1913 and consequently the 1901 (1997) dominant cycle was lost. So too ended the synchrony in the temporal pattern of cycles among cyclic populations. The build-up of runs in the years that followed eventually resulted in less pronounced differences in sockeye abundance among the four cycle lines.

Individual runs rebuilt beginning in 1926, with large increases to the lower 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 along with a five-year fishing closure on early and mid-season run timing groups during 1946-50.

Annual Trend In Run Size For Stocks That Are Dominant On The 1997 Cycle Line

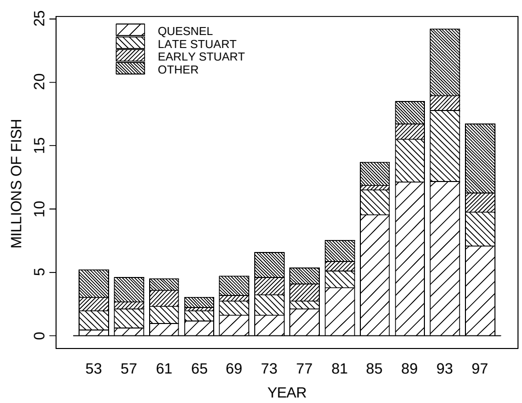


Estimates of the number of spawners on the 1997 cycle line remained relatively constant during 1953-81 and averaged 1.1 million fish/year. Large increases in run sizes on the 1997 cycle have occurred since 1981. The number of spawners, catch and total returns (catch+spawners) increased steadily from 7.5 million in 1981 to 24 million in 1993. The returns in 1993 were the highest on record since 1913.

Populations of sockeye that rear in Quesnel Lake and the largest runs to the Stuart-Takla-Trembleur lakes region (early Stuart and late Stuart Lake runs) are now dominant on the 1997 cycle line. Cyclic populations that return to Shuswap and Chilko Lake are now lowest on the 1997 cycle.

The increase in run size to record levels on the 1997 cycle beginning in 1981 resulted from increases in spawning abundance and higher than average survival rates in the 1980s. Increases in survival were highest for Quesnel Lake sockeye.

Run Size For The 1997 Cycle Line



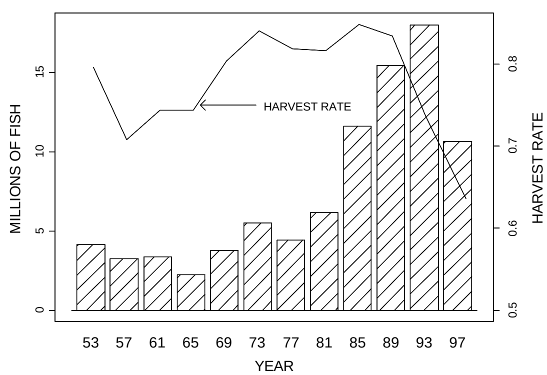
Annual returns of Quesnel Lake sockeye have increased dramatically since the 1950s from <1 million fish in 1961 to 13 million in 1993. Annual returns of early Stuart sockeye on the 1997 cycle have been highly variable with little trend since the 1950s and have ranged from 256,000 sockeye in 1965 to 1.5 million in 1997. The late Stuart run has increased since 1981 with record returns of 3.4 million in 1989 and >5 million in 1993.

The Fishery

Following construction of the first cannery on the Fraser River in 1866, the commercial gillnet fishery developed rapidly. The early commercial fishery was intense and harvest rates on the non-dominant cycles were higher than on the dominant 1901 cycle. Thus it seems likely that cyclic trends in Fraser River sockeye production prior to 1913 were exaggerated and at least partially maintained by different fishing patterns among cycles (e.g. depensatory fishing mortality). Reconstructed estimates of catches ranged from 35-50 million on the 1901 line before 1913. As a result of habitat destruction, the most notable being the effects of the Hell's Gate slide in 1913 and the overfishing in the years that followed, catches declined from 35 million in 1913 to an average of 1.9 million fish/year during

1915-30 for all cycles. During 1930-50 catches increased to an average of 2.6 million fish/year.

Catch And Harvest Rate For The 1997 Cycle Line



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 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, as well as international and domestic catch allocation goals, are met.

Catches on the 1997 cycle have increased linearly in proportion to run size since the late 1960s, from four million sockeye in 1969 to 18 million sockeye in 1993.

This was the highest recorded catch from all years since 1913. In 1993 the troll fishery accounted for 15% of the Canadian commercial catch, the purse seine fishery took 49% and the gillnet fishery took 36%. Estimates of native catches were about 5% of the total estimated catch in 1993.

Canadian commercial catches are mainly 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 occur in northern and central B.C. and within the Strait of Georgia. Sockeye are harvested in native food fisheries throughout the Fraser River watershed. Recreational catches are presently small but estimates of sports catches have recently increased.

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 southeastern Alaska. U.S. catches have remained relatively stable and were about 18% of the total catch in 1993.

Harvest rates on the 1997 cycle have been variable, ranging from 64% in1997 to 85% in 1985, with an averaging of 78%. High Fraser River discharge rates in 1997 resulted in high in-river mortality of migrating adult sockeye. Harvest rates were reduced in 1997 to increase spawning escapement to the Fraser River in an attempt to compensate for the unusually high in-river mortality.

Resource Status

For most sockeye populations, there is little evidence of diminishing adult returns at the upper range of spawning stock sizes observed since rebuilding began in the 1920s and 1930s. For some stocks, we have seen lower return rates in a few years of high spawning stock sizes. For example, sockeye returns to Quesnel Lake have been about 10-12 million fish/year on the dominant cycle line in 1985, 1989 and 1993, despite record increases in spawning stock size of more than two-fold (750,000-1.9 million). Preliminary estimates of returns in 1997 were seven million fish, following a record spawning escapement of 2.6 million sockeye in 1993.

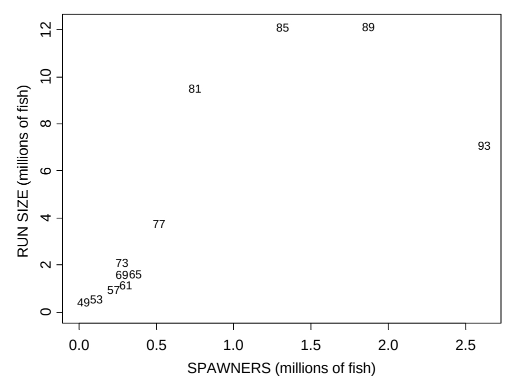
The effect of these high spawner densities on survival is not known. Because of high survival variability, independent of the number of spawners, repeated high spawning levels are required to assess optimal stock sizes under average conditions.

Trends in recruitment at any particular spawning stock are not only affected by random inter-annual variations in survival but also by long-term climatic variations in productivity. Until we have seen spawning stock sizes at repeated and sufficiently high levels, the full potential of Fraser River sockeye will not be known.

Economic yield from the 1997 cycle line has mainly come from a few highly cyclic populations (Late Stuart and Quesnel). Much larger gains on the 1997 cycle depend on the extent to which off-cycle runs of Chilko and Shuswap Lake sockeye can be rebuilt. Less dramatic production increases are also likely if smaller co-migrating 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 maximising Fraser sockeye potential. Even under pessimistic scenarios, increases in yield should result from increases in spawning abundance to off-cycle runs. Certainly, there is no evidence that indicates the current cyclic pattern is optimal. Rebuilding of off-cycle runs that co-migrate with much larger dominant runs on the 1997 cycle require careful consideration of alternative management plans so that short-term economic losses are minimised. Ultimately, the processes that perpetuate population cycles and prevailing climatic factors affecting survival will determine the rate that low runs can be rebuilt to optimal long-term levels.

Relationship Between Number Of Spawners And Resulting Run Size For The 1997 Quesnel Lake Sockeye Cycle Line (Data Points Are Spawning Years)



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