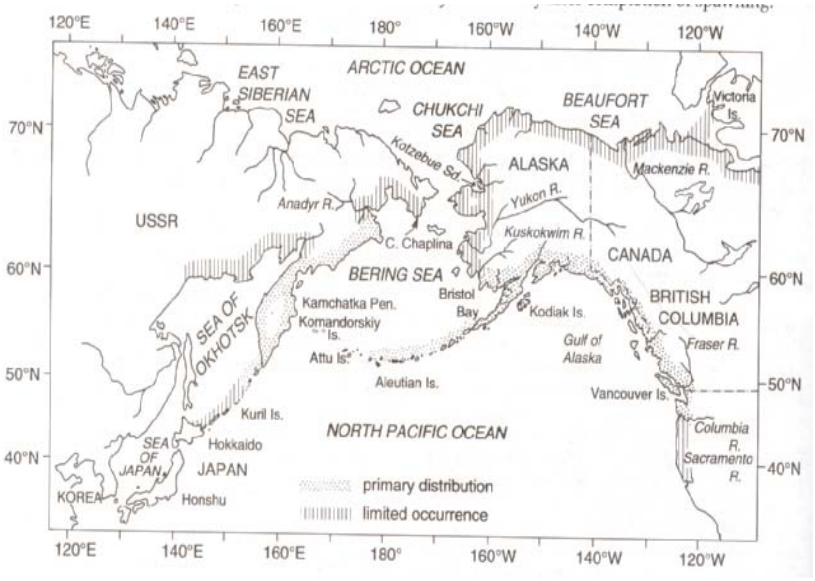
Horsefly Sockeye

Distribution

Worldwide:

Sockeye salmon populations range widely in the temperate and sub-arctic waters of the North Pacific Ocean. In North America, spawning populations are found in streams from the Sacramento River in California north to the Bering Sea and Sea of Okhotsk. Commercial populations are found in Puget Sound, British Columbia and Alaska, and in the Kamchatka peninsula. Of all these, the Fraser River watershed supports more sockeye salmon than any other in the world.



The Fraser River watershed supports more sockeye salmon than any other in the world. It is a river of international concern.

Figure 1. Distribution of Sockeye Salmon in the North Pacific Ocean.

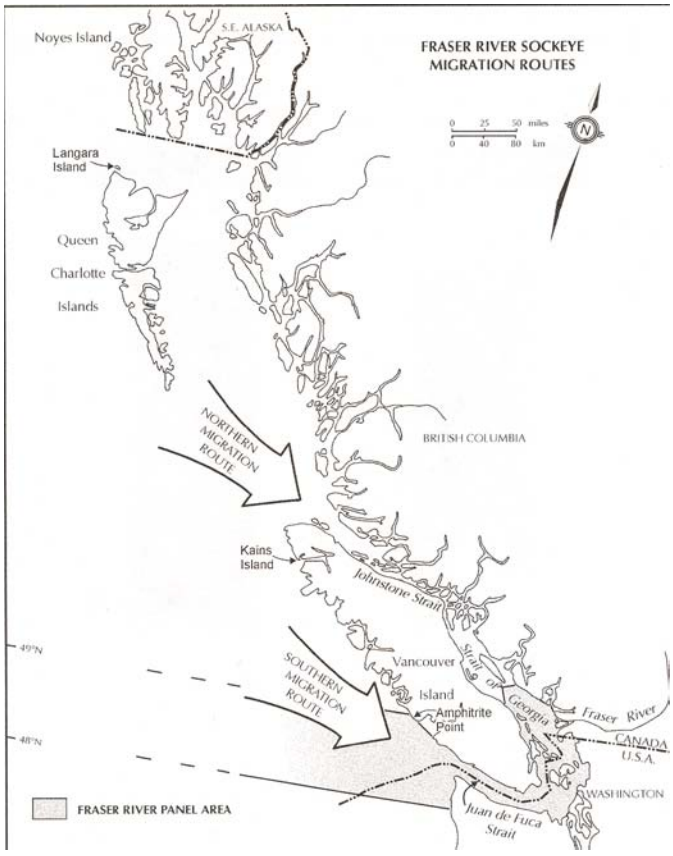
Since salmon pass through international waters and are harvested by at least one other country besides Canada, the federal government is directly involved in their management. The right to fish Fraser River salmon is governed by treaties between Canada and the United States, First Nations fishery agreements, as well as other mechanisms. Catch allocation between the major fleets is addressed politically through a series of consultations between government, First Nations and industry groups, supported by technical science advisors from two countries.

Coastal B.C.:

Overall, the harvest rate on Fraser River sockeye is from 25% to 50% of the total population. Harvest management deals with several dimensions, including:

- The coastal location of the fishery, where fish are intercepted as they migrate;
- The timing of individual stocks as they migrate;
- The socio-economic implications of the harvest/harvest capacity for each fishery; and
- The expected abundance of the stocks, as predicted by science advisors.

Most commercial fishing for Fraser River sockeye occurs in Canadian coastal waters, especially in Discovery Pass near Campbell River, and Juan de Fuca Strait near Victoria.



Commercial fishing for Fraser River sockeye drives the economies of many coastal communities.

Figure 2. Illustration of the northern (Johnstone Strait) and southern (Juan de Fuca Strait) routes for sockeye salmon migrating to the Fraser River.

The details of fishery management and organization are beyond the scope of this summary. It is important to note that due to the number of boats and harvest capacity, the length of time the commercial fishery is open is very short – ranging from a few hours to a few days, only in very specific areas. The largest catch is usually taken by commercial fleets (Canada and the U.S.), then First Nations fisheries, and then recreational fisheries.

Fishery management is complex, and quickly changes. DFO has specialists who deal with this.

Generally, Fraser River sockeye migrate through the fisheries in mid-summer, and can be categorized into four timing groups:

- Early Stuart (Stuart-Takla system)
- Early summer (N. Thompson, Francois-Stellako, Bowron)
- Summer (Horsefly River/Quesnel Lake/Chilko River stocks)
- Late summer (Adams River, Birkenhead/Lillooet)

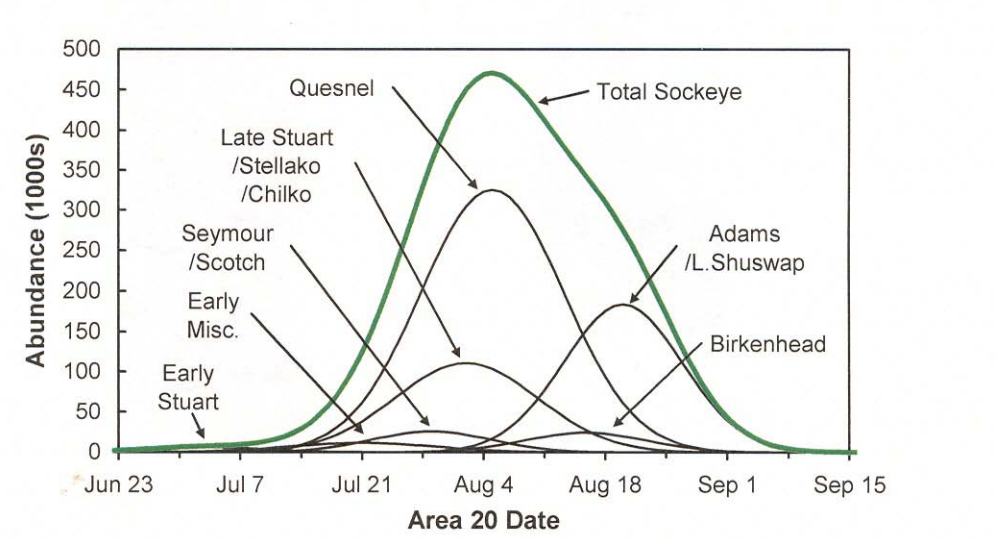


Figure 3. Predicted timing of Fraser River sockeye runs in 2002, through the Juan de Fuca net fishery.

The abundance of Fraser River sockeye fluctuates with many factors; however, since Fraser River sockeye stocks are mostly four-year old fish they exhibit a high degree of cyclic dominance. The Horsefly River un is dominant in the 2005 cycle, and large numbers of sockeye spawners should be expected in 2009.

The remainder of the population that is not harvested is called the *escapement:* this term refers to the spawning population that survives to reproduce in freshwater streams.

Fraser River Escapement:

Populations:

Sockeye salmon require lakes for their juvenile rearing, and therefore sockeye populations are only found in watersheds with substantial lake systems. Larger sockeye populations are found in the Pitt River, Birkenhead, Harrison, Shuswap Lake tributaries (such as Eagle, Adams, Seymour River, Scotch Creek), Lower and Middle Shuswap River, Chilko River, Quesnel watershed (Horsefly, Mitchell Rivers), Stuart-Takla-Trembleur Lakes tributaries, the Nechako (Francois and Nadina systems, Stellako River), and the Upper Fraser River, especially the Bowron. Collectively, these watersheds account for about 1 – 10 million spawning sockeye annually. See large-scale map and table below.

Age Composition:

The age composition of sockeye salmon returning from the ocean to spawn can vary considerably among populations; however, Fraser River stocks are characteristically four-year old fish. The length of time juveniles spend in freshwater is one year after emergence from the gravel, and the length of sty in the ocean is mostly two years.

Some early-maturing males return after only one year at sea, and are known as "jacks". They are much smaller than their 4-year old counterparts, and are sexually mature. A large population of jacks may be an indicator of a large four-year old run the following year "Jills" are uncommon.

Horsefly sockeye are:

- *A large, identifiable run;*
- *4-year old fish, with cyclic dominance pattern;*
- *Affected by fishing rate as well as natural influences.*

Horsefly Escapement:

The Horsefly River contains a spawning population of sockeye salmon which are found from the confluence of the Horsefly River at Quesnel Lake, upstream to natural waterfalls about 27 km on the mainstem river. Spawning sockeye populations are also found in Moffat Creek (to the falls at ~ 8 km) and McKinley Creek into the headwaters.

Table 1. Escapements of sockeye salmon to Fraser River spawning areas[1], comparing Horsefly run with other summer run and Fraser River populations. The Horsefly dominant cycle is shaded.

Escapement Year	Horsefly Watershed Sockeye[2]	All Summer-Run Sockeye	All Fraser River Sockeye
2006	133,000	N/A	N/A
2005	800,100	N/A	N/A
2004	4,500	N/A	N/A
2003	182,3000	N/A	N/A
2002	No data	3,804,000	10,201,000
2001	2,084,100	4,683,000	5,256,000
2000	36,600	1,650,000	2,353,000
1999	139,400	1,282,000	1,831,000
1998	843,900	2,381,000	4,419,000
1997	1,191,900	3,807,000	4,252,000
1996	34,200	1,413,000	2,061,000
1995	178,900	926,000	1,731,000
1994	549,900	1,352,000	3,129,000
1993	1,837,100	5,072,000	6,202,000
1992	5,900	635,000	1,069,000
1991	38,600	1,256,000	3,306,000
1990	439,500	1,597,000	6,064,000
1989	1,614,400	2,553,000	3,060,000
1988	5,900	745,000	1,370,000
1987	16,800	659,000	1,896,000
1986	150,386	581,000	3,658,000

If you're a sockeye, timing is everything.

Spawning and Incubation

Upstream Migration:

The timing and rate of upstream migration of Fraser River sockeye shows peaks of passage of individual spawning runs into the lower Fraser River from the first few days in July to the end of August/early September. Historically, the chronological order of the various runs is very consistent, and this allows an unusual degree of precision in the management of the fisheries.

The different run groups move upstream at different rates: the Quesnel-Horsefly summer runs travel at a rate of about 50 km/day from the lower

[1] Data from Annual Report of the Pacific Salmon Commission, Fraser River Panel.
[2] Data from 2003 – 2006 personal communication K. Benner, DFO Science Branch.

river fishery to the spawning grounds. In recent years, there has been evidence of the unusually late timing of the migration of some of the runs (especially the late summer run at Adams River), correlated with high water temperatures. This has caused changes in fishing patterns, and in the manner in which DFO estimates run sizes and total stocks.[3]

Salmon usually cease feeding before entering freshwater and depend on their energy reserves for migration, maturation of gonads, spawning and redd defence until death. They undergo remarkable physical, chemical, bio-chemical and physiological changes during migration which extensively deplete body reserves of fat and protein. Upriver spawning populations have been known to lose 90% of their body fat reserves, 30-60% of their initial body protein, and an overall weight loss for females at more than 30%.

In their ascent to spawn, sockeye take advantage of slower water and eddies along the stream banks to conserve energy. They travel in schools, and during heavy migrations they form a continuous, moving band on one or both sides of the river, migrating steadily and uniformly close tot the bottom where the current is slower.

Spawning:

Sockeye salmon are unique among the Pacific salmonids in their dependency upon lake rearing during the juvenile stage. Accordingly, sockeye spawning areas are usually adjacent to lake rearing areas – in this case, Quesnel Lake.

While sockeye salmon generally spawn in late summer and autumn but the time of spawning for different stocks can vary greatly as an adaptation to local survival conditions. In the Fraser River, the difference among stocks in spawning timing is related directly to the temperature regime of the spawning site: spawning is later in the warmer incubation environments. The rate of development of the embryos is faster at higher temperatures, so this flexibility allows all the fry to emerge at a synchronized time in the spring (See Figure 4).

Horsefly sockeye spawning extends over about a 6 week period, with the peak of spawning activity occurring about the second week in September.

The character and suitability of the areas utilized for spawning depend greatly on a number of physical factors: headwater rivers, tributary creeks, rivers between lakes, outlet rivers, spring areas and submerged areas of lake beaches are utilized to varying degrees. Spring-fed ponds

[3] Not sure who, PSC?

and sidechannels also tend to be more heavily utilized by sockeye salmon than by the other species.

Sockeye salmon spawn in gravel that is small enough to be readily dislodged by digging but large enough to be stable around the areas where the eggs are deposited. Since redd-digging tends to remove the silt and clean the gravel where the eggs are deposited, this process is more efficient in streams where the current carries the material downstream. Water depth is not a critical factor, and lake spawners can extend to considerable depths. Sockeye can detect upwelling groundwater areas along lake beaches and in spring ponds and spawning is usually heaviest in these areas.

Spawning behaviour is similar for all salmon species. A female will select a site, dig a depression (redd) parallel to the stream current, deposit a batch of eggs, which are simultaneously fertilized by one or more attendant males. She then covers the eggs, rests a little and digs another redd. Typically a female will dig 4 to 5 redds and then guard the site until death. This method generally yield 100% fertilization and each redd would contain 500 – 1,100 eggs. The length of time females remain on or over their redds varies from a few days to about two weeks.

Sockeye have an energy budget when migrating and spawning.

Heavy pre-spawning mortalities from disease or parasitism have occurred in numerous instances in some Fraser River spawning areas, including the Horsefly River (documented in 1961). Timing of the runs and temperatures in the Fraser River during the upriver migration appear to be factors which are related to pre-spawning loss (IPSFC 1976). A classic example is the effect of the obstruction in the Fraser River canyon at Hell's Gate from 1911 to 1913, when sockeye salmon ere blocked or delayed in migration at certain flows and vast numbers died without reaching their spawning destinations.

Incubation:

Like all the salmon species, fertilized eggs are very shock-sensitive, and there is usually some mortality following successful egg deposition. Floods, ice jams and other events that shock, exposure, displacement into less favourable incubation conditions or predation. Also, crowding on the spawning grounds and "wave" spawning can result in repeated excavations of the same gravel by subsequent females, with associated egg mortality.

Sockeye eggs develop under the gravel first into eyed eggs (which are much less shock-sensitive) and then hatch into "alevins", or larvae by late November or early December. The rate of development is temperature dependant, but alevins are present and mobile before the deep freeze in

late winter. This allows them to move around somewhere to avoid de-oxygenated zones. By early April yolk sacs are used up and fish begin to emerge from the gravel (the "emergence" period) when they become visible, free swimming, and are known as salmon "fry."

Horsefly Spawning Channel:

Spawning channels work by optimizing the hydrologic conditions necessary for good egg-to-fry survival. Important features of channel design include controlled flow, clean graded gravel, stable bank conditions and sometimes in-stream structures to manipulate the number of spawners per area.

The Horsefly Sockeye Spawning Channel was constructed in the late 1980's, first operating in the 1989 brood year. The original objective was to rebuild the Horsefly River sockeye stock to historic levels in the subdominant and off-years. It also provides a conservation function in the event of a catastrophic loss of eggs due to some natural event. The spawning channel provides an available spawning area of 15,200m^2 and is designed to accommodate 12,200 females.

Emergence:

Sockeye alevins emerge from the gravel after nightfall. They accumulate just below the gravel surface and emerge when the inhibitory effect of daylight is removed. There are other behavioural changes that cause them to actively swim downstream as individuals, and migrate directly to rearing lakes, in this case downstream to Quesnel Lake. Emergence begins in early to mid-April, peaks in early to mid-May, and ends in late May to early June.

Peak emergence is condensed to a short time frame in the spring, which is a synchronized event throughout the Fraser River populations. The seasonal timing of sockeye fry emergence corresponds with optimal time of dispersal into their feeding habitats, taking advantage of the seasonal peak abundance of zooplankton of appropriate size. Successful reproduction for this species depends on a balance between the timing of spawning, incubation temperatures and emergence timing.

Freshwater Residence:

Fry migration

Following emergence, sockeye fry exhibit behavioural changes that cause them to change from an individual to a schooling response, to positive photo taxis, and to positive rheo taxis. In short, they move upstream in

schools, during the day. The route and complexity of the migration pattern depends on the location of the ultimate nursery area with respect to the spawning area from which the fry emerge. Horsefly River sockeye fry move directly downstream to Quesnel Lake where they remain for a full year.

Since fry emerge in many different habitats, both upstream and downstream of lake rearing areas, the different races exhibit specific migratory routes. The wide variety of migration patterns that sockeye fry possess require complex mechanisms to control this: we now know it is governed by genetics. Because of the innate behaviour patterns among the different stocks and races, sockeye do not move around easily. This has been documented since the 1970's, which has influenced scientific direction around how to enhance and develop sockeye pop0ulations.

During movement into nursery lakes, fry exhibit directional preferences which are innate and population-specific, tied to the particular river-lake system. Movements can be direct and immediate, or sequential feeding in littoral areas within the lake, or in-river migrations, or midsummer interlake migrations, etc. The timing of these patterns of movement coincides with zooplankton blooms in the nursery areas.

Freshwater Life

There is a large body of literature that describes how sockeye salmon utilize lakes for rearing. Sockeye fry eat a variety of zooplankton that meet size-specific requirements. Complicated seasonal and diel patterns of movement are related to zooplankton migrations, as well as a balance between metabolic advantage and predator avoidance.

DFO annually measures juvenile sockeye abundance and growth in Quesnel Lake.

Quesnel Lake has been the subject of a number of limnological studies which are beyond the scope of this report to details. Generally, it is Considered to be oligotrophic (that is, nutrient poor): whether or not it is underutilized by rearing sockeye is under review. DFO has an annual monitoring program that investigates zooplankton abundance, sockeye fry movement and growth, and estimates of the size of the juvenile sockeye population. The number, size and condition of out-migrating sockeye are one indicator of the commercial run size two years hence.

Annual growth of juvenile sockeye varies hugely from lake to lake and from year to year. Scale patterns are laid down in such a way that migrating Fraser River sockeye can be racially identified based on the scale characteristics that identify their nursery lake. Emergent fry weigh

generally 0.1 – 0.2 g and after a year of lake growth may emigrate in the 4 – 8 g size range.[4]

Competition and predation

Competition for food and space in lakes may exist, but is mostly seen among large populations of sockeye fry rather than between competing species. In B.C., some species are known to have some overlap with juvenile sockeye in lake distribution and food habits (stickleback, pond smelts, some whitefish), but in most of the Fraser River system no significant, potential competitor populations are evident.

Rearing sockeye are especially vulnerable to predation during migration periods: at emergence and also during lake emigration. At these times predators congregate along the corridors attacking from above (birds, such as gulls, mergansers) and beneath (coho yearlings, bull trout, sculpins, lake trout, rainbow trout, northern pikeminnow).

Yes, sockeye and kokanee fry can compete – assuming we can tell them apart.

Kokanee

Kokanee are a genetically distinct form of sockeye salmon that have fully adapted to a freshwater existence and presumably diverted from a common anadromous stock in recent geologic times. They are similar to anadromous sockeye in their life history and habitat requirements, but differ in their small size and early spawning timing. The principle food of kokanee is zooplankton, and the potential exists for intraspecific competition in lakes where both kokanee and anadromous sockeye are present.

Since kokanee are a freshwater sport fish they are managed by the Provincial Ministry of Environment, rather than by D.F.O> The possibility of competitive interactions between kokanee and sockeye fry in Quesnel Lake has been a subject of discussion between the two agencies.

Seaward Migration

If you're a young sockeye, you are born knowing your way out of the lake.

Anadromous fish that prepare to migrate downstream to the ocean undergo significant changes that allow them to change habitats: this process is called "smelting" and the fish themselves "smolts." They undergo physiological and behavioural modifications to allow them to survive in an ocean habitat. Their external appearance also changes considerably: sockeye smolts become slimmer, more streamlined, and silvery.

Methods used by smolts to find their way to the lake outlet have been the subject of much research since the 1960's. There are different mechanisms at work, including a "built-in GPS" orientation system,

[4] Pacific Salmon Life Histories, p. 45, R.L. Burghner.

combined with celestial navigation and inherited directional preferences. It is clear that among juvenile salmonids, sockeye salmon seem to have the most highly developed navigational capabilities.

Most sockeye lakes are covered by ice in winter, and the smolts usually begin to move downstream within days of ice breakup and with the accompanying slight warming of lake outlet waters. In Quesnel Lake, this would be in May. Migrating smolts leave the lake in schools, orient downstream, and swim faster than the current where the flow is uniform and quiet. Sockeye have been recorded traveling about 40 km/day downstream; however, other details of their long migration to salt water are not well known.

Ocean Residence

It is beyond the scope of this report to detail this segment of sockeye life history experience. Horsefly River sockeye experience a short period of early sea life in the Fraser River estuary near Vancouver, before entering near shore environments in the Strait of Georgia by late May. From there, they travel northwestward along the coast of British Colombia and Alaska, and later in the year distribute in the eastern North Pacific Ocean and eastern Bering Sea. Sockeye distribution is related to major oceanographic features, salinity, temperature etc. and considerable mingling of North American and Asian stocks occur.

There is a large body of literature on the ocean life history of sockeye salmon, generated mostly by scientists from Canada, Japan and the United States. Generally, the ocean environment allows them to grow very quickly: after two years at sea they return to coastal waters at an average weigh to 2.73 kg (6 pounds).

Ocean survival of sockeye salmon, from the smolt to harvestable adult stage, is a subject of considerably research. Changing ocean conditions have caused scientists to re-evaluate predictive methods, particularly where Fraser River sockeye are concerned.

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