


# A REVIEW AND HISTORY OF MAJOR ARTIFICIAL SALMON SPAWNING CHANNELS IN BRITISH COLUMBIA.

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# ABSTRACT

The first artificial spawning channel in the Pacific Northwest was built in 1954 to compensate for spawning grounds affected by hydroelectric development. Since that time, 22 major spawning channels have been constructed to provide improved salmon spawning habitat. Other channel technologies generally built on smaller scales include groundwater-fed side channels for spawning and protected over-winter rearing habitat, semi-natural channels that are complexed to enhance rearing habitat, and upwelling incubation channels. Of the 22 major spawning channels, eight are currently operating as per their original design, nine have been converted for hatchery use, one is intact but currently not operated, and three were severely impacted by flood events and one has been decommissioned.

Egg-to-fry survival in spawning channels is typically over 50 percent or approximately three to five times that of natural rivers. Siltation is a major factor affecting productivity and requires ongoing cleaning of the spawning gravel to maintain high egg-to-fry survival rates. Clean, stable lake fed water supplies and optimized gravel mixes provide the most desirable conditions for productive spawning channels. Flood events that deposit heavy sediment loads or are physically destructive have been the demise of some channels in unstable watersheds.

Fin clipping studies have found channel and river origin fry to have similar freshwater and marine survivals. The Babine Lake and Big Qualicum River Development Projects, and the Weaver Creek spawning channel have been very successful producers of adult salmon and have supported major commercial fisheries. However, their effect of increasing harvest rates in mixed stock fisheries has been a concern. Reduced harvest rates to protect weaker stocks has led to surplus escapements of enhanced fish and contributed to the development of terminal commercial fisheries known as Excess Salmon to Spawning Requirement (ESSR) fisheries at channel sites and in Babine Lake.

Another concern has been potential increased competition of enhanced fish with other stocks in freshwater and marine environments. Increased fry production from Babine spawning channels has not affected freshwater survival of co-resident non-enhanced stocks but a density effect has been found between smolt weight and total wild plus enhanced fry production in Babine Lake.

Elevated levels of prespawn mortality have occurred more frequently over the past two to three decades and have been associated with parasite infections and higher water temperatures. Spawning channel operations have been modified to address parasites and temperature, but the same parasites have also been found in wild stocks in both the Skeena and Fraser River systems where their effects are less well monitored. Reduced productivity has been documented among both enhanced and non-enhanced sockeye stocks on the Fraser system. A 2017 COSEWIC assessment found 10 of 22 Fraser sockeye stocks examined to be Threatened or Endangered. These stocks were from all sockeye timing groups and throughout the Fraser watershed, and included the Harrison Upstream Migrating sockeye to which Weaver are the major contributor. The Anderson-Seton and Nadina-Francois early summer groups, which include the Gates and Nadina channel stocks were found to be not at risk. Hinch et al. (2011) noted that climate change forecasts of increasing temperatures will likely translate into more frequent elevated prespawn mortality events for temperature sensitive stocks. Spawning channels with water storage and lake water pumping facilities have been able to respond to climate change effects and mitigate low flow, high water temperature conditions.

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Cover photos by: top and right, Tavish Campbell; left, Nicole Christiansen; centre, Doug Lofthouse

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*Fulton Spawning Channel 2, Babine Lake, British Columbia.*
*Photo by: Doug Lofthouse*

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# INTRODUCTION

In the mid-1900s, it was known that egg-to-fry survival of salmon and trout in natural rivers varied widely, ranging from one to over 90 percent and probably averaging 10 percent or less (Clay 1991). Clay noted that by constructing artificial spawning channels that mimicked the best natural conditions, high egg-to-fry survival rates could be more consistently attained. Fry from artificial channels were also expected to have similar viability as natural fry, resulting in increased adult returns.

The first artificial spawning channel in the Pacific Northwest was constructed in 1954 for pink salmon in the Jones Creek (Wahleach) watershed, followed by the NcNary Chinook channel on the Columbia River in 1956 and the Robertson Creek Chinook spawning channel in 1960. Artificial spawning channels were an emerging technology and specifications for channel design were drawn from published studies of observations on wild salmon spawning populations. A description of the early specifications for gravel size, water flow, slope and area required per spawning pair is provided by Clay (1961).

From 1960 to 1989, the Canadian Federal Department of Fisheries and Oceans (DFO) and the Canada-US International Pacific Salmon Fisheries Commission (IPSFC) constructed artificial spawning channels on the Fraser and Skeena rivers and Vancouver Island. These were typically located on lake-fed river systems, the spawning gravel was screened to remove fines and large cobble, and some channels had associated water storage works to maintain or improve spawning and incubation flows. Adult spawning densities were also controlled to maximize fry production.

Between 1984 and 1990, DFO built several “unmanned” spawning channels, so called because they were intended to operate with minimal staffing and assessment programs to reduce operational costs. Most were located in remote coastal inlets and one was built on the Chilko River system. However, some of the coastal channels had short operational histories due to flashy river systems that caused major flood damage.

To date, a total of 22 major artificial salmon spawning channels have been constructed by DFO or the IPSFC throughout BC (Fig. 1 next page). Many have since been decommissioned or converted to rearing or semi-natural channels and the early Chinook and coho channels have been replaced by hatcheries.

Photo by: Nicole Christiansen

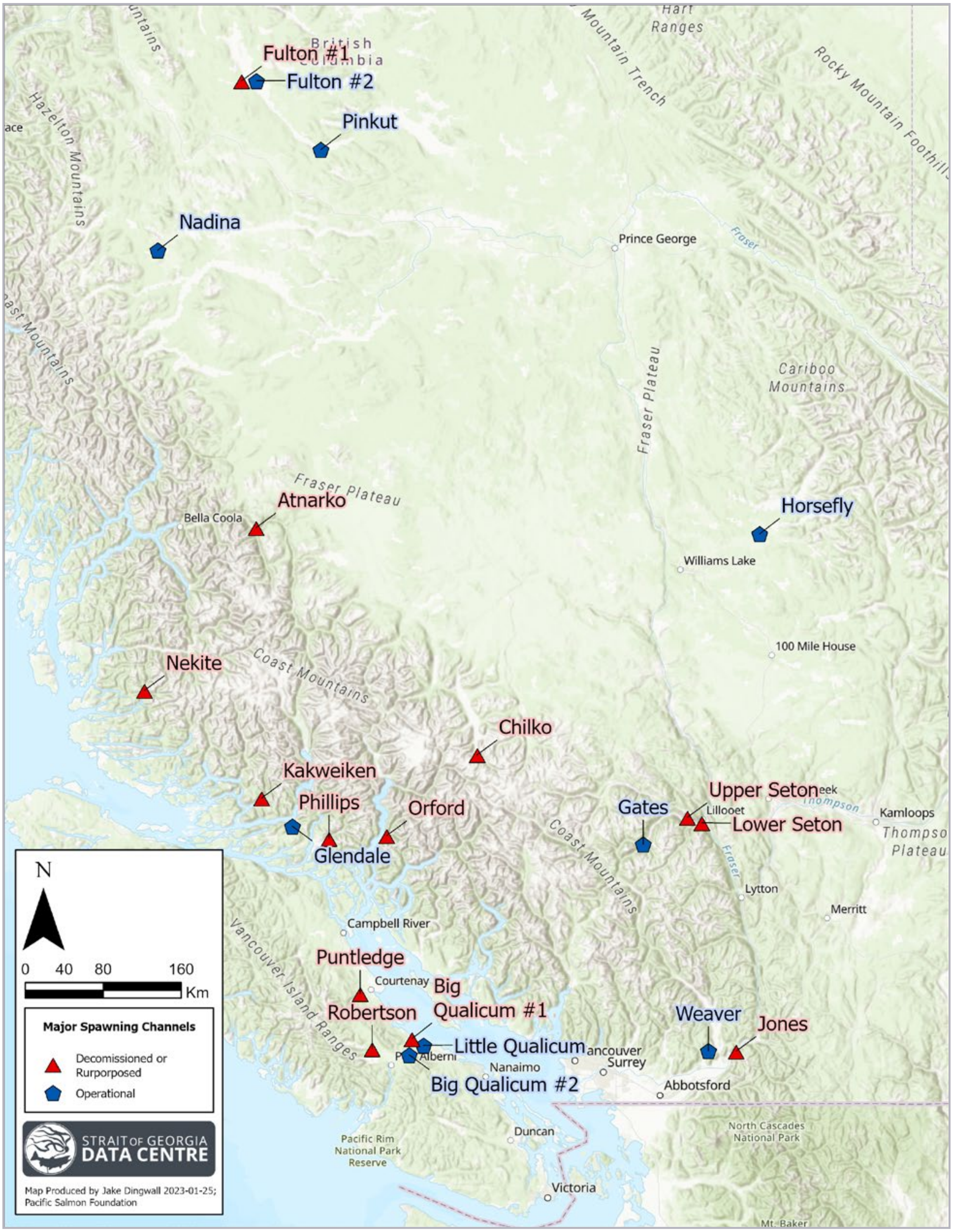



**Figure 1:** Geographic locations of major spawning channels in BC.

The IPSFC also developed upwelling incubation channel technology, and after field testing at the Quesnel research facility, an upwelling channel was constructed on the upper Pitt River at Corbold Creek for sockeye in 1963 (Roos 1991). Salmon eggs incubated to the eyed-egg stage in hatchery trays would then be planted in upwelling gravel channels for volitional release of the emerging fry. The facility operated until the mid-1990s when the program changed to hatchery production and satellited from the Inch Creek hatchery in Mission, BC.

In 1978, DFO began developing groundwater fed side channels from relic or seasonal channels to create additional or improved spawning areas. Groundwater fed side channels are typically smaller than the surface water fed artificial spawning channels, some use a combination of surface and groundwater, and spawner entry is volitional. Bonnell (1991) reviewed the construction, operation and evaluation of groundwater-fed side channels and reported that "since 1978, more than 40 groundwater fed side channels have been built in British Columbia." An important distinction is the use of existing "native" gravel without removal of fines which is more resistant to siltation than the screened gravel used in major spawning channels. Egg-to-fry survival may be lower than in screened gravel but is maintained at elevated levels longer without cleaning, making it more suitable for lower maintenance projects with heavier silt loads (M. Sheng pers. comm.).

Spawning channels for provincially managed kokanee have been constructed in the Okanagan and South East BC. Kokanee channels are not included in this report but information can be found on the BC Ministry of Environment and The Friends of Mission Creek Society websites.

The objectives of this report are to review the history, significant operational issues and production from the major artificial spawning channels. The majority of these channels monitor adult spawners, egg deposition and fry to assess juvenile production. Assessment of adult production is more limited. The marine harvest of Big Qualicum chum is estimated by fin clips, and Skeena and Fraser run reconstruction models estimate sockeye contribution to fisheries by stock but cannot distinguish channel from river origin fish.

Design specifications for the major salmon spawning channels are listed in Appendix 1. Egg deposition, fry production and egg-to-fry survival data used for this report are listed in Appendices 2 to 18.

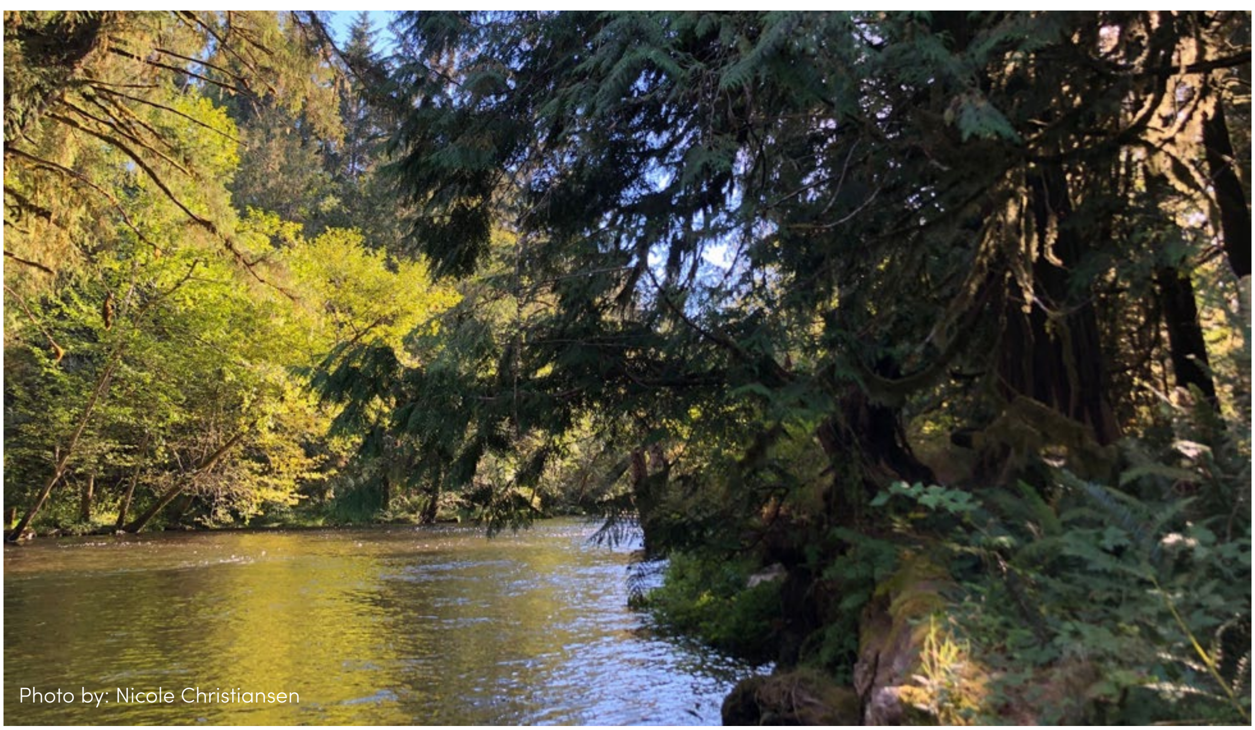


Photo by: Nicole Christiansen

# METHODS

Channel efficiency was compared using egg-to-fry survival. Data on fry production and egg deposition were obtained from the Department of Fisheries and Oceans Salmonid Enhancement Program (SEP) Enhancement Planning and Assessment Database (EPAD), published reports, unpublished records from enhancement facilities, and from interviews and files of current and retired DFO staff. Access to records at DFO facilities was limited by Covid restrictions.

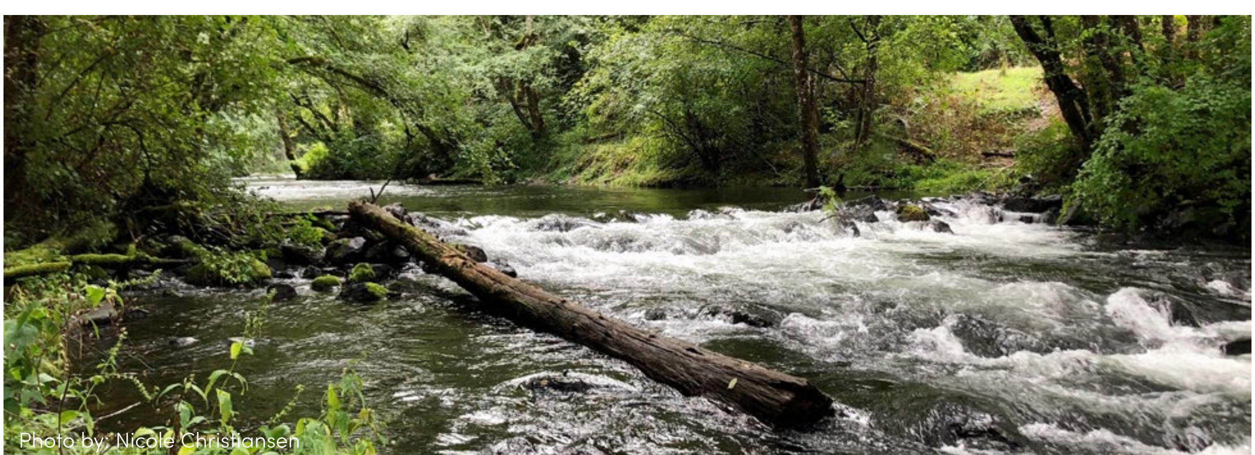
Egg deposition per square metre was used as a common metric to allow comparison of freshwater production between different sized channels and within channels for years with different spawning densities. The use of egg deposition also removed variability resulting from annual variation in sex ratio, fecundity, prespawn mortality and egg retention. However, egg deposition is not consistently included in EPAD or SEP production reports and often required extraction from unpublished records provided by SEP facilities and assessment staff. For some channels data for some years was not available.

Information on adult spawning escapements to river systems before and after channel construction was obtained from published reports and DFO's New Salmon Escapement Database System (NuSEDS).

Prespawn mortality (PSM) is reported by two different methods, as prespawn mortality or spawning success. At the Fulton, Pinkut, Big Qualicum and Horsefly spawning channels, and Nadina channel since 1994, female carcasses are examined for egg retention or if they died unspawned, and egg retention and PSM are reported separately. Other projects such as Weaver channel use the common field survey practice of estimating females as, e.g. 100, 50 or 0 percent spawned, and report spawning success as the equivalent number of females that would have spawned 100 percent successfully. The author is not aware of any assessments of the accuracy of egg deposition estimates and data sets with individual samples were not available to compare the two methods. PSM and the converse of spawning success are assumed to be similar and the consistent use of either method at each channel is a good indicator of trends in prespawn mortality.

Escapement or spawning density targets vary between species, channels and over time. Design densities for the early channels were based on published observations of different species spawning in natural rivers and assumed 50:50 sex ratios. Spawning density targets for individual channels have been adjusted over time to increase fry production and are often operationalized by controlling entry into the channel to meet a target numbers of females.

Adult production estimates for Skeena and Fraser sockeye channel projects were provided by DFO Stock Assessment Division staff. These estimates are based on run reconstruction models with DNA information but the models and DNA cannot discriminate between channel and river-origin fish. Separate channel and river contributions could be estimated by the proportion of channel and river origin fry, if river production was known, but was not done. Big Qualicum adult chum production estimates are based on mark recovery of fin clips and taken from Fraser et al. (1983) for brood years 1962 to 1975 and from Lynch et al. (2020) for brood years 1980 to 2016.



# JONES CREEK SPAWNING CHANNEL

The Jones Creek spawning channel was built in 1954 by the BC Electric Company (BCEC) to replace spawning area lost due to construction of a BCEC dam in the Jones Creek (Wahleach) watershed in 1952. The spawning channel would be operated by DFO and maintained by BCEC. The channel was primarily intended to maintain the pink salmon run and operated every second year although smaller runs of chum, coho, and steelhead also used the system (Fraser and Fedorenko 1983; Hartman and Miles 1997). This review discusses only pink salmon.

The experimental nature of this first spawning channel is illustrated by the evolution of several design features. Fraser and Fedorenko (1983) described modifications to the channel exit in 1954 and again in 1973 to improve upstream migration of chum and pink salmon. Channel width increased in the early years due to erosion of the unarmoured margins by spawners, freshets, ice scouring, and maintenance activities, but the margins eventually stabilized with regrowth of natural vegetation. Gravel size was modified in 1973 from the original mix of 6mm to 38 mm that was similar to preferred spawning areas in Jones Creek and other natural streams, with the addition of larger gravel from 19 mm to 102 mm to improve porosity. A second settling basin was added in 1956 and in 1973 it was enlarged and invert controls added to reduce velocities to deal with persistent siltation problems. Hartman and Miles (1997) illustrated the accumulation of fines between 1954 and 1959, and Clay (1991) noted that it was necessary to rake the gravel annually to remove silt carried in from the creek, and to remove and screen the gravel every five years.

Adult enumeration programs varied over the years. Prior to 1949, Fishery Officers estimated adult spawners in Jones Creek by periodic visual observations. In preparation for the spawning channel program, a more accurate estimate was made in 1949 using live and dead counts and tag recovery. Live counts were conducted in 1950 and live and dead counts in 1951. After channel construction, a combination of live counts and dead recovery, and in some years channel fence counts, were used to estimate adult spawners in the channel and creek. A detailed description of adult enumeration methods was provided by Fraser and Fedorenko (1983).

Spawning channel fry were enumerated by inclined plane trap, and egg-to-fry survival was calculated using egg deposition estimates from the adult enumeration and sampling program. Fry production and egg-to-fry-survival estimates up to the 1993 brood year, after which the channel ceased operations, are summarized by Hartman and Miles (1997). Fry survival averaged 40.5 percent with low production years associated with heavy siltation. Fry production also varied widely but averaged around three quarter million fry (Fig. 2).

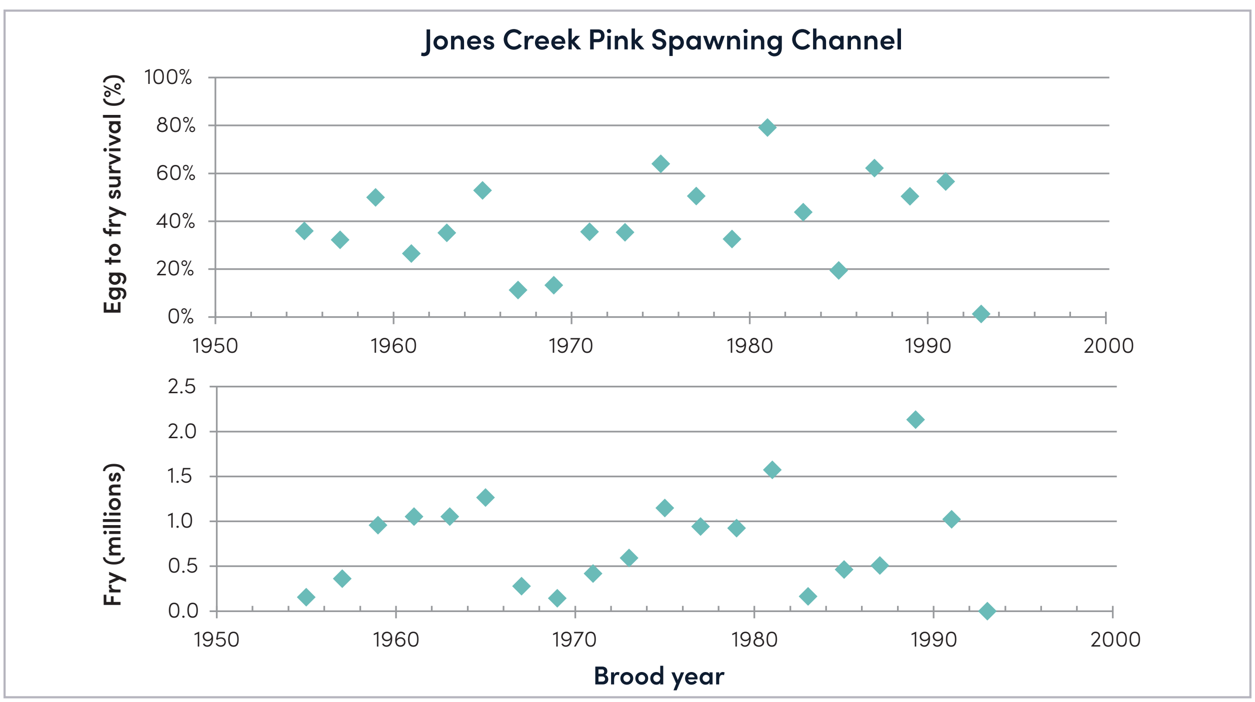



**Figure 2:** Salmon egg-to-fry survival (%) (top); and fry production (millions) (bottom), brood years 1955 to 1993.

Natural fry production from Jones Creek was not assessed. Fraser and Fedorenko (1983) and Hartman and Miles (1997) estimated natural fry production using the 1982 SEP biostandard of 13 percent egg-to-fry survival for Fraser River pink salmon (Lill et al. 1985) and egg deposition estimates based on visual counts of adult creek spawners and sex ratio, fecundity and egg retention estimates from the spawning channel. Estimates of freshwater (egg-to-fry) survival for Fraser River pink salmon reported by the Pacific Salmon Commission (PSC 2019) averaged around 14 percent in the 1960s and 1970s, but declined to around 7 percent in the 1980s and 1990s. The PSC has not published Fraser River pink salmon egg-to-fry survival estimates since 2001 (Fig. 3).

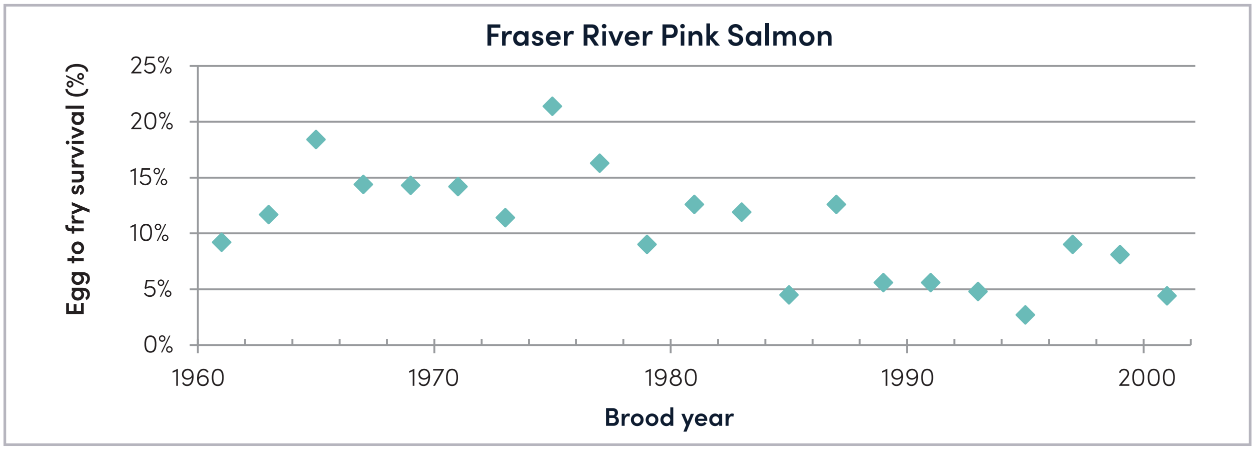



**Figure 3:** Fraser River pink salmon freshwater egg-to-fry survival (%), brood years 1961 to 2001.

Hartman and Miles (1997) considered the Jones Creek spawning channel to have been only partially successful at meeting its objective of maintaining the pink salmon run in the Jones Creek system. Although fry production averaged three quarter million which is close to the expected fry production of 6,300 natural spawners that the channel was intended to replace, spawning escapements to the Jones Creek system averaged only 2,639 during years of channel operation.

The channel was built to mitigate the loss of spawning and incubation habitat caused by reduced flows following the construction of a hydroelectric dam. The channel was always prone to siltation and fines carried in from the creek but this was exacerbated by logging and road construction on steep slopes in the 1970s. In 1993 the channel suffered catastrophic siltation when rain storms and flooding caused extensive slope and road-related landslides. The 1993 brood had very few spawners in the channel (83 females) and an extremely low egg egg-to-fry survival of 1.2 percent. Due to BC Hydro's concerns over increasing costs of maintenance, the channel was not cleaned and ceased to operate after the 1993 brood. For the next few cycles eggs were taken for incubation at the Chilliwack River hatchery and the fry were transported back to Jones Creek.

In 2005, BC Hydro, successor to the BCEC, implemented minimum flows for spawning and for incubation and rearing as recommended by the Wahleach Water Use Plan Consultation Committee. A fish productivity monitoring program was also carried out from 1999 to 2013 which provided spawner and fry production information for pink and chum and limited information on coho and steelhead (BC Hydro 2014).

An interesting note was the attempt to establish an even-year return of pink salmon to Jones Creek. In 1954, 2.7 million pink salmon eggs were transplanted from Lakelse River on the Skeena River system, resulting in a return of 2,800 adults to the channel in 1956. This resulted in an estimated deposition of 2.78 million eggs to which an additional 1.0 million eggs from Lakelse River were transplanted. The transplanted run, however, died out after two or three cycles and no further records of even-year pinks in Jones Creek were provided (Fraser and Fedorenko 1983).

# ROBERTSON CREEK SPAWNING CHANNEL

The Robertson Creek spawning channel was built in 1960 in response to construction of a hydroelectric dam on the Somass River system and an associated dam on a secondary outlet at Robertson Creek. The spawning channel was intended to increase Chinook and coho stocks in Robertson Creek and transplant pink salmon into the Somass River system (DFO 1960, Lim and Barrett, 1982).

The channel was designed for maximum use of the available site and when constructed in 1960 was the largest channel of its kind in North America. The channel was also intended to support research with three separate sections, trap and transport facilities that allowed adult spawning density to be adjusted, juvenile rearing channels, and an experimental test flume to study diversion screens for downstream juvenile migrants and ergonomics of adult upstream migrants (DFO 1960, Clay 1961).

The grading curve reported by Clay (1961) shows a notable change in gravel size from the original mix placed in the Jones Creek channel. The Robertson Creek mix included larger gravel up to 4 inches and greater removal of fines under ¾ of an inch. This mix with larger gravel and fewer fines was intended to increase porosity and water flow through the gravel. This mix was also subsequently used in other DFO and IPSFC spawning channels.

Between 1959 and 1964, pink salmon eggs from the Bear (Amor de Cosmos Creek) and Tsolum rivers on Vancouver Island, the Atnarko River on BC's central coast, and the Cheakamus and Indian Rivers on the BC mainland were incubated at the Robertson Creek or Puntledge River hatcheries and planted as eye eggs into the channel. Egg-to-fry survivals were very high but adult returns were poor in all but one year and the pink transplant program was discontinued in 1967 (Lim et al. 1982).

Information on Chinook and coho production was not available, but Childerhose and Trim (1979) noted issues with adult coho, some of which normally migrate through Robertson Creek to spawn in upper tributaries. Coho being held in the channel frequently died unspawned.

The spawning channel was converted for coho rearing in the early 1970s (D. Lawseth pers. comm.).

# PUNTLEDGE RIVER SPAWNING CHANNEL

The Puntledge River spawning channel was built in 1965 to rebuild the summer-run Chinook population. Since the early 1900s, summer-run spawners had numbered around 3,000 but following an expansion of hydroelectric facilities, beginning in 1953, the run decreased to about 400 spawners annually (due to losses of natural spawning area, diversion of water creating adult migration delays and injury, and mortality of juveniles in powerhouse turbines). Adult passage was improved by the construction of weirs at the lower Stotan Falls and moderation of flows during the main migration period, and a spawning channel was constructed in 1965 to replace lost spawning grounds below Comox Lake. The channel outflow was also located downstream of the powerhouse bypass dam enabling juvenile migrants from the channel to bypass the turbine intake works (Lister 1968, Marshall 1973).

Egg-to-fry survival in the first year of operation is believed to have been affected by an interruption in the pumped water supply to the channel, which was subsequently corrected by the installation of an automatic start on the backup pump. Egg-to-fry survival then ranged around the expected 40 percent until siltation caused a decline to a low of 11.6 percent survival of the 1970 brood. Marshall (1973) provided detail on attempts to restore incubation survival. Hydraulic sampling and test holes revealed heavy siltation and many dead eggs below a depth of one foot. Following an inadequate gravel scarification in July 1971 followed by another poor survival of the 1971 brood, more extensive gravel cleaning was carried out in 1972. Incubation flows were also increased, starting with the 1970 brood, from 50 cfs to the spawning flows of 100 cfs and maintained through to fry emergence. Figure 4 (next page) shows that egg-to-fry survival did not increase in 1973.

MacKinnon et al. (1979) noted that in the fall of 1973, surface run-off was observed to be eroding the banks of the channel and carrying fine silt particles into the channel. Ditching and seeding of the banks, and cleaning of the gravel a third time in 1973 was not followed by increased survival. The highest egg-to-fry survival occurred in the 1975 brood after spawners were restricted from the top section of the channel; however fry production was low due to the low number of spawners.

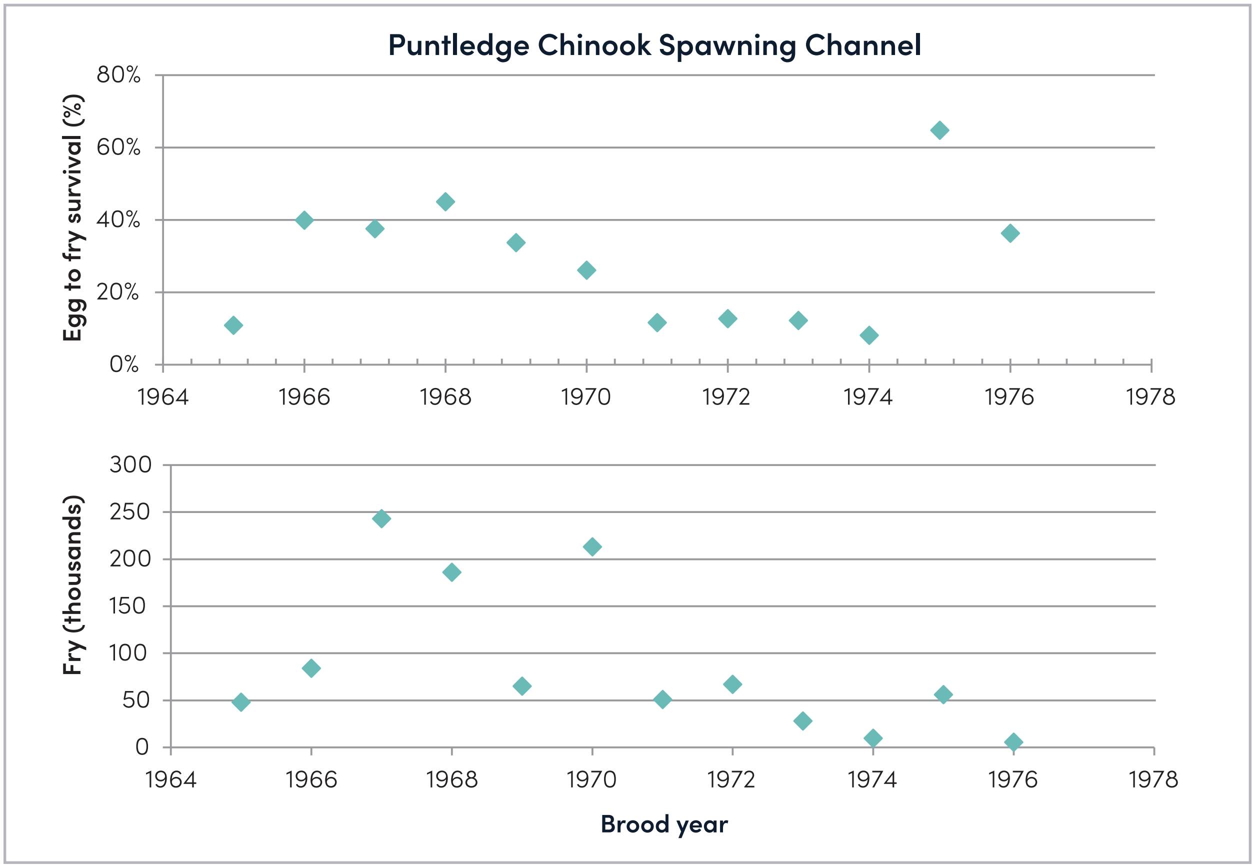



**Figure 4:** Puntledge Chinook egg-to-fry survival (%) (top) and fry production (thousands) (bottom), brood years 1965 to 1976.


Photo by: Eiko Jones

# INTERNATIONAL PACIFIC SALMON COMMISSION SPAWNING CHANNELS

Between 1957 and 1973, the IPSFC built five artificial spawning channels and operated them until 1986 when they were transferred to the Canadian Department of Fisheries and Oceans under the 1985 Pacific Salmon Treaty (1985, www.psc.org ).

## UPPER SETON SPAWNING CHANNEL

In 1957, the Canada U.S. Sockeye Salmon Fisheries Convention was amended by ratification of the Pink Salmon Protocol, making the IPSFC responsible for protection and extension of Fraser River pink salmon.

Studies by the IPSFC in 1957 and 1958 estimated 25,000 square metres of spawning habitat had been lost due to construction of the Seton Lake hydroelectric dam and the remaining area was fully utilized by the current stock. This led to a recommendation for construction of an artificial spawning channel and plans were made for a channel with 5,333 square metres of spawning area and potential for future expansion to an ultimate size of 14,783 square metres (IPSFC and Dept. Fisheries 1959).

In 1961, the IPSFC built the Upper Seton spawning channel for pink salmon with 5,033 square yards of spawning area as partial compensation of the lost spawning area in Seton Creek. This was the first spawning channel built by the IPSFC and was regarded as an experimental facility (Cooper 1977).

Rosberg et al. (1986) described how the channel was operated only for the odd-year pink cycle. The water supply was not turned on until late September to prevent sockeye from entering the channel and the channel was dewatered after fry emergence. Pink salmon density was controlled by allowing unobstructed access until visual observation estimated the target number of adults had been reached whereupon a weir was installed across the outlet to prevent further access. The final spawner and egg deposition estimates were provided by deadpitch, i.e. manual counting of carcasses and sampling for biological characteristics such as fecundity, egg retention, age (other species), sex and length (Rosberg et al. 1986, Brad Thompson pers. comm. 2022).

The 1957 study found a spawning density of 1.6 fish per square yard (1.05 m2/female) in the preferred spawning area of Seton Creek. Cooper (1977) noted that in the spawning channel, 0.6 to 0.7 females per square yard (1.2 to 1.4 m2/female) was initially considered optimum for maximum fry production but later data suggested maximum pink fry production could be attained by increasing densities to 0.9 females per square yard (0.9 m2/female).

Fry enumeration was conducted by a variety of methods, initially by extrapolating a total capture estimate from part of the channel, then partial sampling with fyke nets correlated with one year of the total capture estimate, followed by dye-mark recapture and fyke net, and then fyke net using previous correlations. Egg-to-fry survival averaged 52 precent over the operation of the channel. Figure 5 (next page) indicates a minor decrease in average survival at higher egg densities. Rosberg et al. (1986) noted that channel operations staff thought the fyke net sampling should be replaced by a more accurate method.

Adult production from IPSFC pink salmon channels was estimated by prorating channel fry production with the total estimate of Fraser River pink salmon fry and subsequent adult returns (Cooper 1977). The accuracy of this extrapolation is unknown.

After ratification of the 1985 Canada-US Pacific Salmon Treaty, all IPSFC channels and associated staff were transferred to DFO under which the channels continued to operate. In the late 1980s, the manager of the Seton Spawning Channels was transferred to the Tenderfoot Creek Hatchery and Seton Channel operations were contracted to the Cayoose Creek First Nation on whose reserve the lower channel was located.

## LOWER SETON SPAWNING CHANNEL

In 1967, instead of expanding the upper spawning channel to meet the recommendation to create more spawning area for pink salmon, the Lower Seton spawning channel was built with 17,463 square metres of spawning area.

As with the Upper Seton channel, adult pink salmon were allowed free access until visual estimates indicated the channel had reached capacity after which access into the channel was barred by installation of a weir at the channel exit. The final spawner count and adult sampling were provided by deadpitch. Fry from the lower channel were enumerated by a more accurate 5 percent sampler, a revolving cone that sampled 5 percent of the fry for subsequent counting or volumetric estimation. Davis and Hiltz (1971) reported that tests in 1970 found the sampler to retain between 4.43 and 5.22 percent of fry with standard deviations ranging from 0.06 to 0.14 percent. Site specific indexes are calculated for samplers at each IPSFC channel. Egg-to-fry survival over the life of the lower spawning channel averaged 64 percent which was higher than the 52 percent of the upper Seton channel.

Cooper (1977) suggested that large fry outputs from the upper and lower Seton channels could be attained at up to 0.9 females per square yard (0.93 m2/female), equivalent to egg depositions of approximately 1,800 to 2,000 eggs per square metre. Figure 5 shows that egg-to-fry survival declined slightly but fry production per square metre still increased above this density.

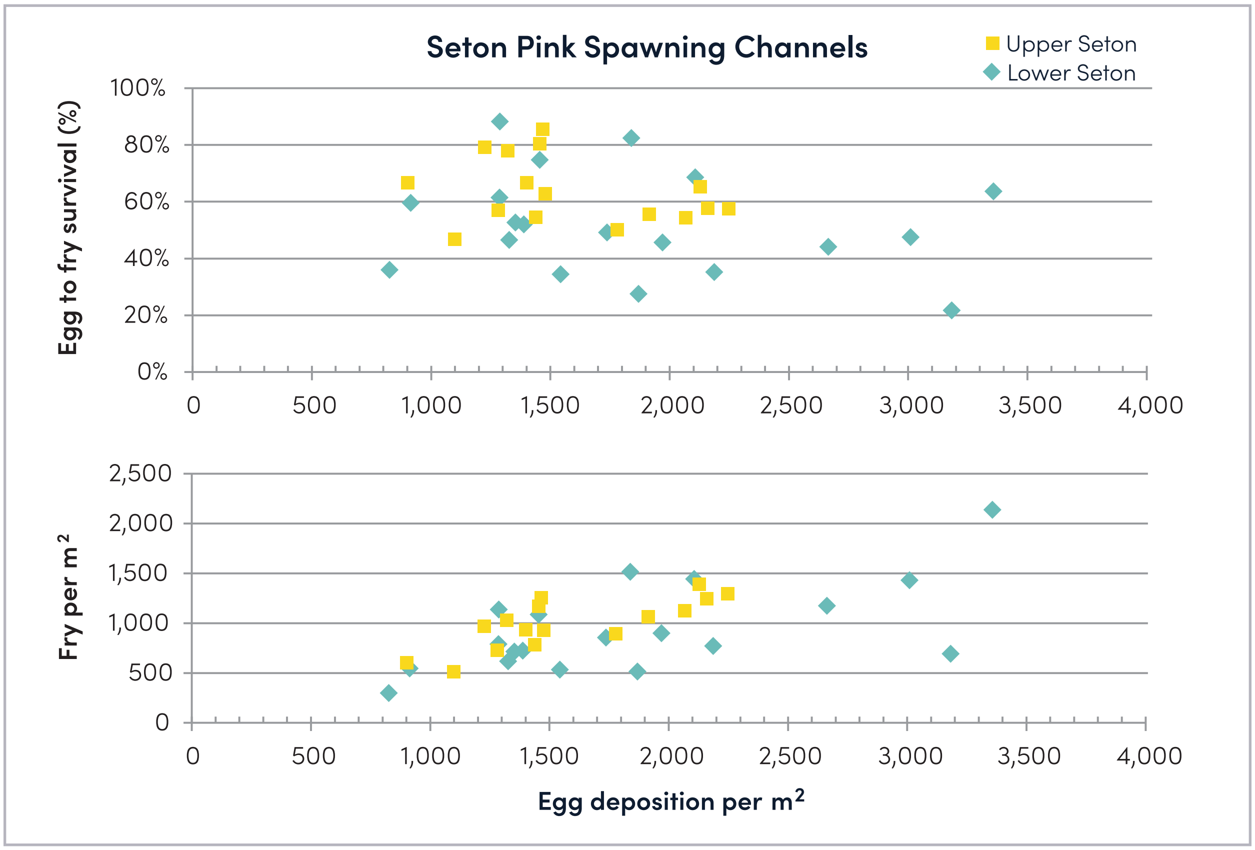



**Figure 5:** Upper (teal diamonds) and Lower Seton (yellow squares) spawning channels pink salmon egg-to-fry survival (%) (top); and fry production per square metre versus egg deposition per square metre (bottom).

## CONVERSION OF THE SETON SPAWNING CHANNELS

In 1998, the upper and lower Seton channels were converted from seasonally operated pink salmon spawning channels to semi-natural channels with year round flow and open access for spawning and rearing of anadromous and resident species (Tisdale 2000).

Operation as seasonal pink salmon spawning channels ended in 1998. Tisdale (2000) noted that the intent was changed to operate the upper channel for both spawning and rearing purposes (anadromous and rearing species). Blair (2019) noted that both Seton channels were re-complexed in 2003 and continuous flows maintained since 2004. Adolph (2003) describes the habitat complexing of the lower channel in 2003.

Surveys of the Seton semi-natural channels are reported by Splitrock (2015, 2019). In addition to finding juvenile Chinook, coho, sockeye and pink salmon, resident bridgelip suckers, bull trout, coast-range sculpins, longnose dace and red sided shiners have been found.

## WEAVER CREEK SPAWNING CHANNEL

The first artificial spawning channel for sockeye was built by the IPSFC in 1965 on Weaver Creek, a tributary to the Harrison River on the lower Fraser River system. Cooper (1977) reported the original gravel screening specifications were the same as the Upper Seton pink channel with a maximum sieve size of three inches (maximum sieve size for sockeye channels is commonly four inches). Rosberg et al. (1986) reported the design depth and velocity of the channel were based on observations of preferred spawning areas in Weaver Creek. The channel was further designed to operate with spawning flows that would minimize drawdown of Weaver Lake. The primary water supply from Weaver Creek is inadequate at times therefore two auxiliary supplies were provided, gravity fed siphons to draw water from Weaver Lake and discharge into the creek approximately 200 metres below the lake outlet, and flow diversion from Sakwi Creek to Weaver Creek above the channel inlet. Use of Sakwi Creek is monitored closely as it is prone to heavy silt loads and its colder water can form frazzle ice on the spawning channel gravel.

*Weaver Creek Spawning Channel, aerial view looking northwest.*

*Weaver Creek Spawning Channel*
*Photos by: Doug Lofthouse*

Adult loading was initially by the same method used for the Seton channels, open access until visual observations determined the channel was fully loaded and then installation of a weir to prevent further spawner entry. The final count and adult sampling were provided by deadpitch. In 1977, a splitter gate was installed to allow chum and pink to be manually diverted back into the creek. Sockeye could likewise be diverted into the channel, creek or to a collection facility for surplus fish. The splitter also provides control of sex ratio allowing increased female to male ratios to maintain higher egg deposition without over-taxing the sometimes limited water supply with surplus males.

The abrupt increase in survival in 1989 is believed to be due to implementation of a ‘dry turning’ procedure to remedy armouring of spawning gravel (stratification with larger cobble on the surface) which results from repetitive cleaning by the air/water gravel cleaner (D. Lofthouse pers. comm.). Over the past decade, egg-to-fry survival has averaged 56 percent compared to the previous thirty year average of 67 percent from 1989 to 2010. The decreasing trend is not significant ($p>0.05$) but the average of the recent decade is significantly less than the previous period ($p<0.005$). Since 2008, six years of low fry production have been due almost entirely to low spawning escapements and egg depositions (Fig. 6).

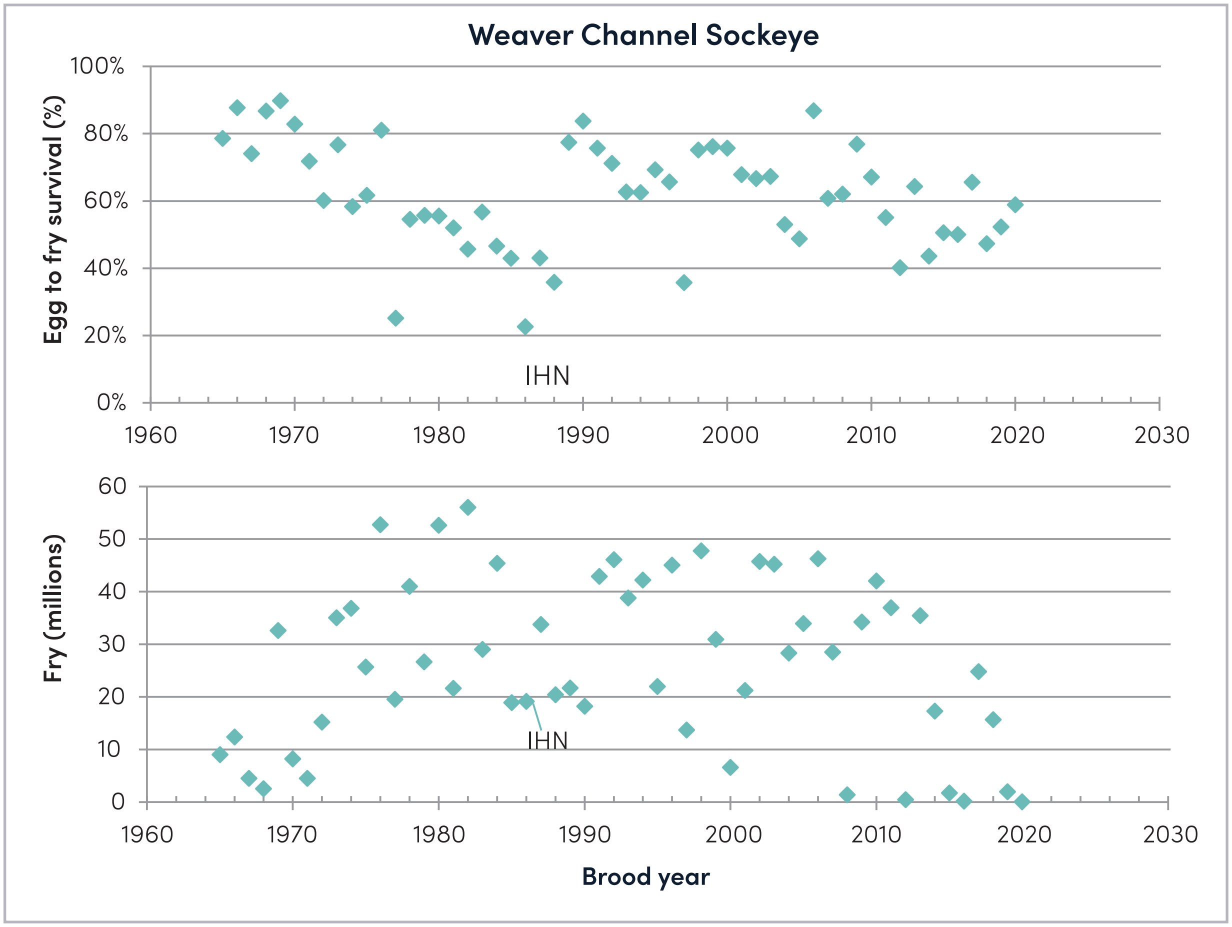



**Figure 6:** Weaver channel sockeye fry survival (%) (top); and fry production (millions) (bottom), brood years 1965 to 2020. IHN indicates when outbreak of Infectious Haematopoietic Necrosis (IHN) occurred in 1987.

The Weaver spawning channel has maintained high egg-to-fry survival rates at egg densities approaching 4,000 eggs per square metre or approximately one square metre per female, which is higher than the target densities of other sockeye spawning channels. Egg-to-fry survival has a slight negative but not significant ($p>0.20$) relationship with egg density up to 7,000 eggs per square metre but fry production has continued to increase over the observed range of egg density (Fig. 7).

An outbreak of the Infectious Haematopoietic Necrosis (IHN) virus occurred in the spring of 1987. A total of 19.1 million fry migrated from the channel with and estimated egg-to-fry survival of 22.6 percent. However, observation of mortality among fry held for 4 day periods sequentially throughout the migration found that half of the fry may have died after leaving the channel (Traxler and Rankin 1989). The channel operator reported that no adverse environmental conditions had occurred during the incubation period which might have contributed to the outbreak.

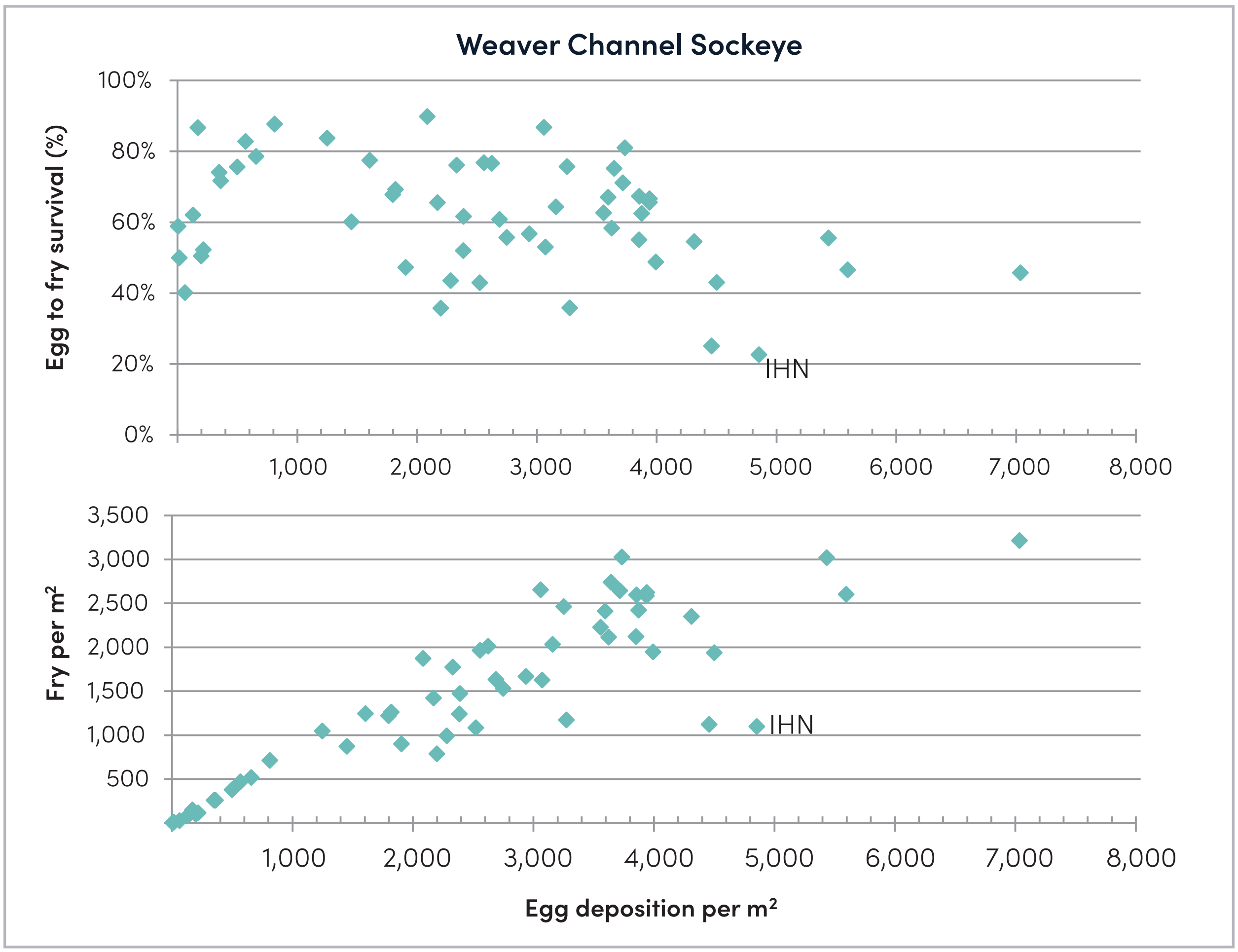



**Figure 7:** Weaver channel sockeye egg-to-fry survival (%) (top); and fry production per square metre versus egg deposition per square metre (bottom). IHN indicates when outbreak of Infectious Haematopoietic Necrosis (IHN) occurred.

Historic estimates of PSM at Weaver channel are indicated by records of spawning success, a combined measure of PSM and egg retention used to estimate the equivalent number of successfully spawned females. Figure 8 shows that spawning success from the mid-1960s to mid-1990s averaged 95 percent or a PSM rate of about 5 percent until 1995 when *Ichthyophthirius multifiliis* ("Ich" or white spot disease) caused PSM losses of over 30 percent. In 1996, the myxozoan parasite *Parvicapsula minibicornis* was detected in PSM losses of over 20 percent and is thought to be the main pathogen associated with elevated PSM in Weaver channel. Since 1995, spawning success has averaged 84 percent, an equivalent loss of over 10 percent of the female spawners, and since 2006 six brood years have had female losses of over 20 percent.

*Parvicapsula* is contracted in the lower Fraser River water column, has been found in sockeye stocks throughout the Fraser River and has been associated with PSM events in both natural and channel stocks (Lofthouse 2017).

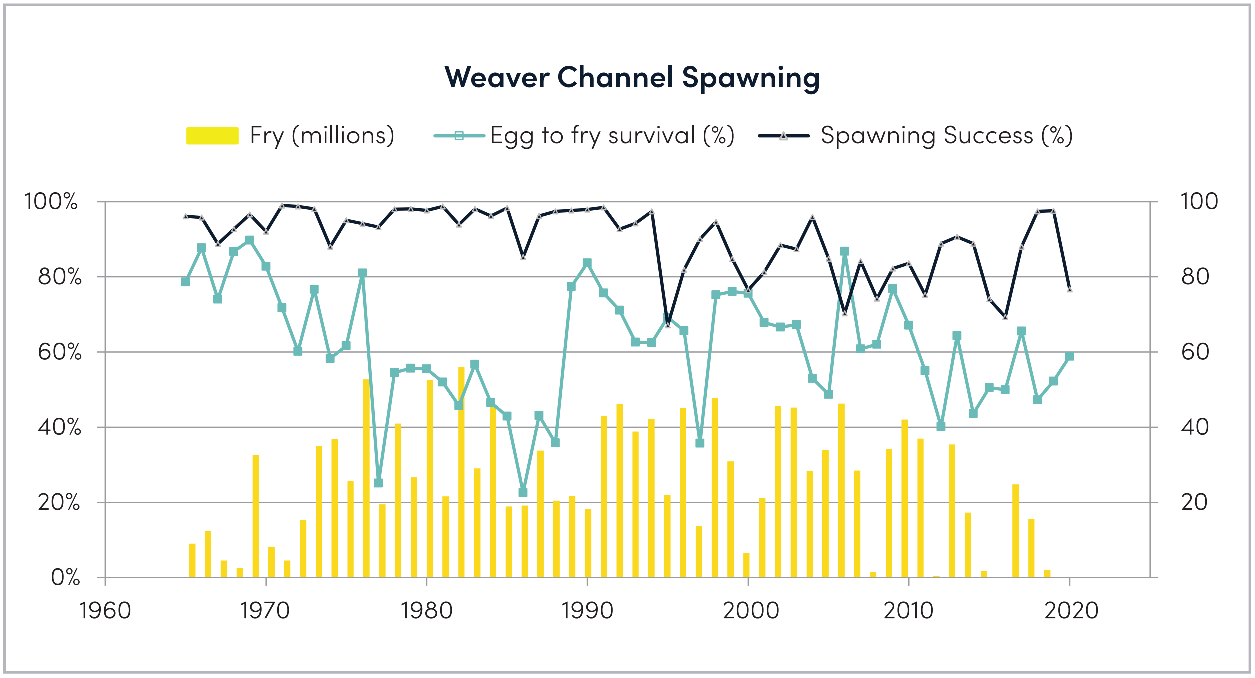



**Figure 8:** Weaver channel female sockeye spawning success (%) (dark blue line), egg-to-fry survival (%) (teal line), and fry production (millions) (yellow bars) for brood years 1965 to 2020 (data from DFO Weaver channel files).

The data do not show a correlation between egg-to-fry survival and spawning success ($p>0.50$). Egg-to-fry survival has dropped slightly, averaging 53 percent in the last decade. Fry production has been affected by low escapements. Figure 9 shows six extremely low years of escapement since 2008.

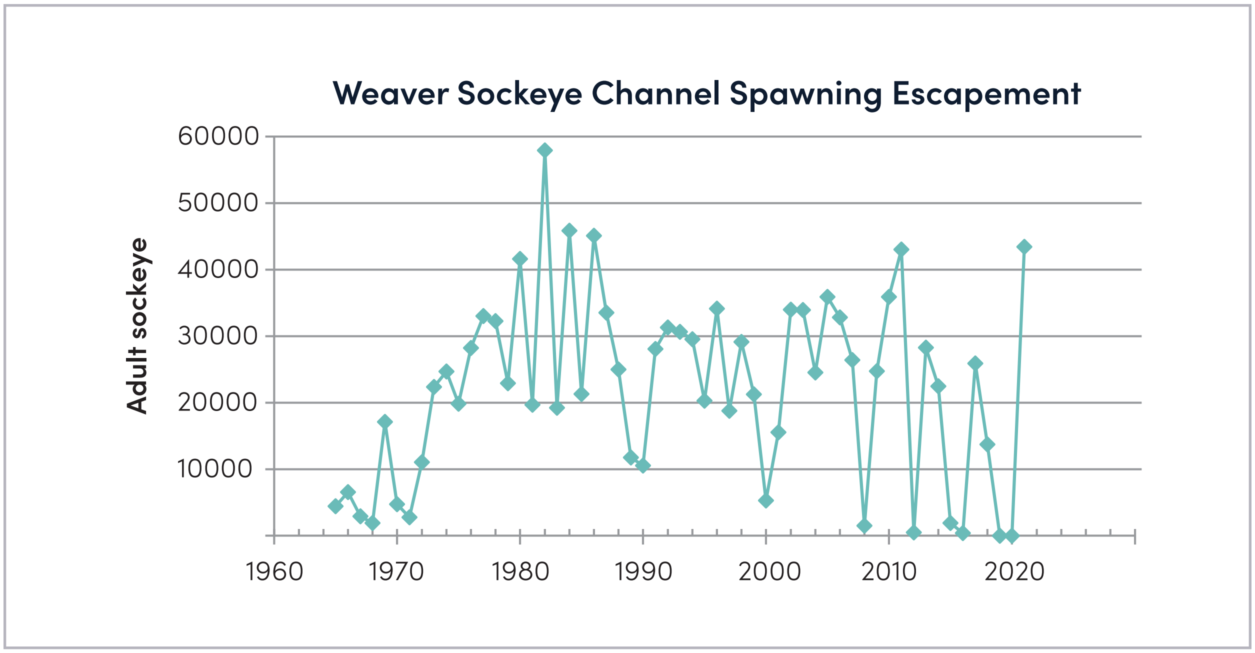



**Figure 9:** Weaver channel sockeye spawning escapement, 1965 to 2021 (data from DFO Weaver channel files).

Cooper (1977) reported leakage from the unsealed spawning channel but did not consider it to have affected fry production. Flow monitoring studies by SEP in the 1980s found a dynamic groundwater influence in the intra-gravel environment and hypothesized that groundwater influence contributed to higher egg-to-fry survivals. West and Mason (1987) found the Weaver channel to be more productive at higher egg depositions than the Nadina or the BLDP channels.

In 2022, the channel could not be operated normally due to a unique and critical water shortage. The unusually dry fall resulted in a lower than normal water table causing water to leak from the channel at a great rate, leaving spawning gravel exposed in some lower sections and only a minimal outflow at the channel exit. Water storage in Weaver Lake would run out by the spring if an increased draw was used to maintain regular flow throughout the full length of the channel. The decision was made to partially load the channel and spawners used the upper section of the channel where flow was adequate.

Weaver Creek has runs of chum and pink salmon that overlap with the sockeye run timing. Historically, these species have averaged around 3,000 and 2,500 spawners in the channel respectively. Some chum and pink are allowed into the channel generally later than the sockeye, which move into the upper section of the channel (D. Johnson pers. comm.).

### Adult Production from the Weaver Creek System

Adult returns of the Weaver, Gates, and Nadina sockeye stocks have been estimated by the IPSFC (up to 1985) and the PSC from 1986 onwards through scale pattern analysis, timing and run-reconstruction and, beginning in 2002, using a heavy reliance on DNA. Neither DNA nor scales can distinguish spawning channel versus natural stream origin adults, which for PSC purposes are rolled up as single stocks (Steve Latham, PSC. pers. comm.). Cooper (1977) provided separate estimates for channel and creek origin adult returns by prorating relative channel and creek fry production.

Sockeye returns to the Weaver Creek system (creek plus channel) averaged 304,000 fish from 1971 to 2020, compared to 84,500 pieces reported by Cooper (1977) for pre-channel brood years 1948-1964. Figure 10 shows increasing annual returns through the 1990s. However, returns declined over the past two decades and have been at pre-channel levels in five of the last 10 years.

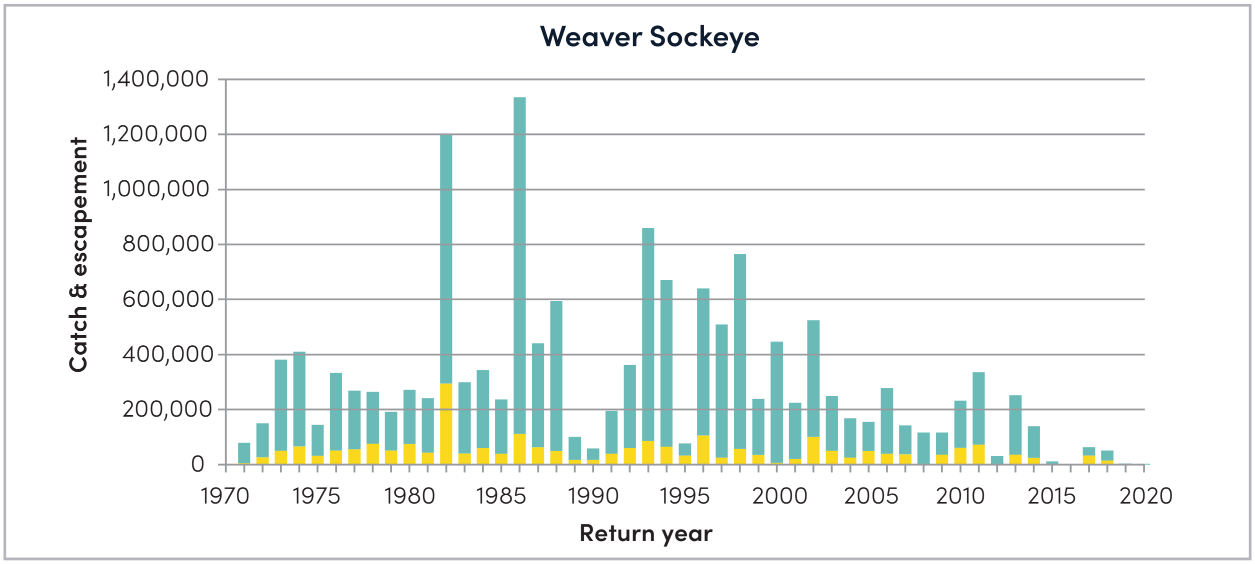



**Figure 10:** Weaver sockeye (creek + channel) catch and escapement, catch (teal) above escapement (yellow), return years 1971 to 2020 (data source: NuSEDS and DFO Stock Assessment Division).

Adult recruits per spawner shows an increasing frequency of low productivity in recent years (Fig. 11). To examine patterns in adult productivity, estimated total fry production from the Weaver system was compared against adult returns (catch plus spawners), which provides an estimate of in-lake plus marine survival. Compared to recruits per spawner, fry-to-adult survival shows a more pronounced but not significant ($p>0.50$) decreasing productivity trend over the past two decades.

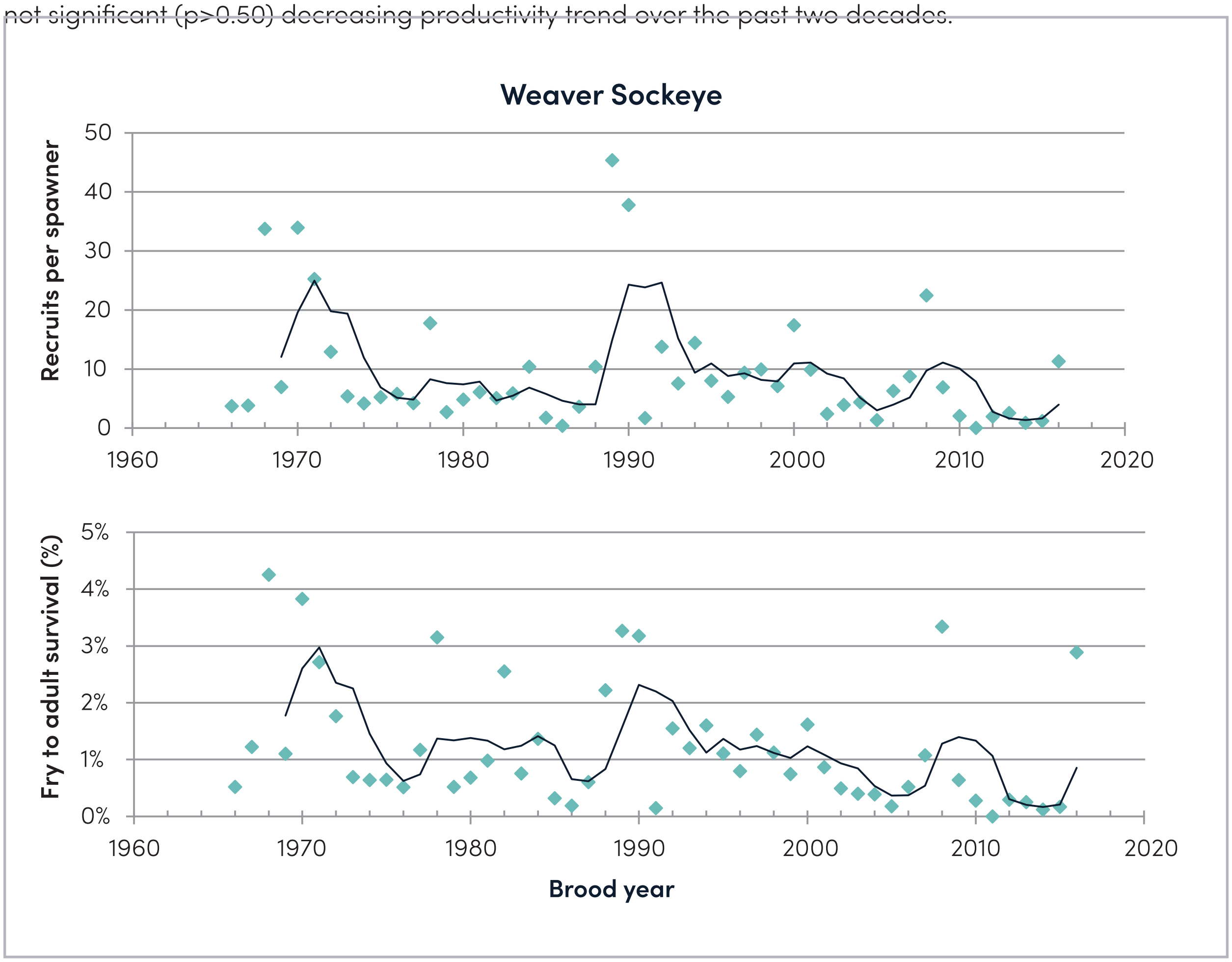
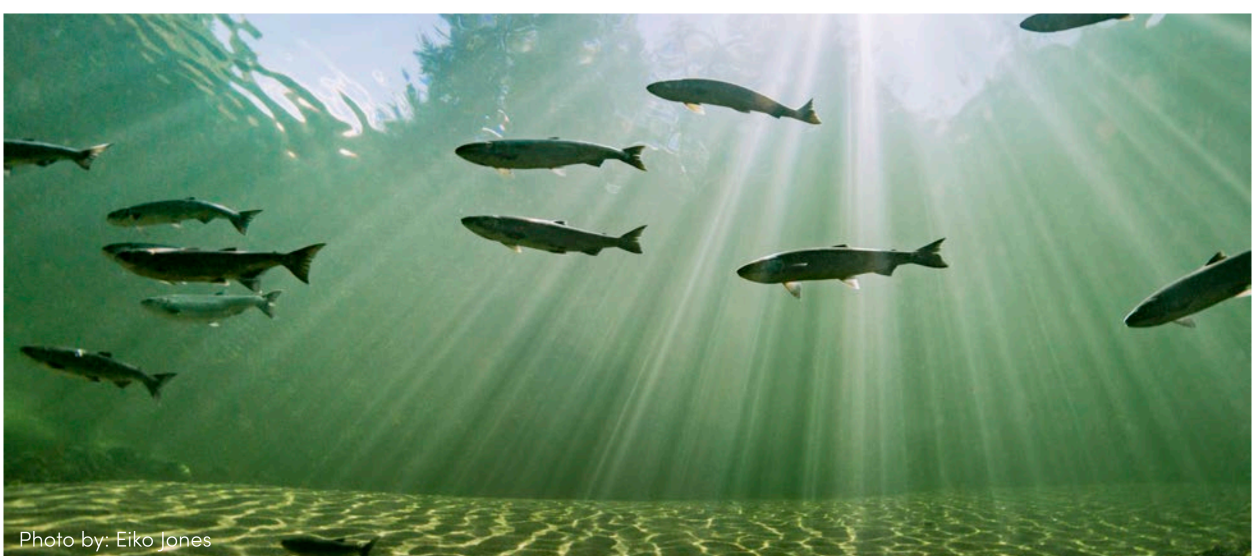



**Figure 11:** Weaver system (creek + channel) recruits per spawner (top); and fry to adult survival (%) (bottom) with 4 year moving averages, brood years 1966 to 2016 (data from DFO Stock Assessment Division).



For the fry-to-adult analysis, total fry production from the Weaver system was estimated by adding creek production to that of the channel. Fry production from the creek was enumerated by the IPSFC for brood years 1965 to 1984 (Rosberg 1986). Estimates for the missing years were made by applying a logarithmic function fitted to the IPSFC fry/spawner data to creek escapements reported in NuSEDS. Escapements less than the IPSFC data were fitted to a linear regression from the origin to the lowest observed IPSFC spawner estimate.

Estimated fry production from the creek averaged only seven percent of the total system fry output since 1965 and only five percent or 1.3 million fry over the past twenty years, and hence would not materially affect estimates of total system fry production (Fig. 12).

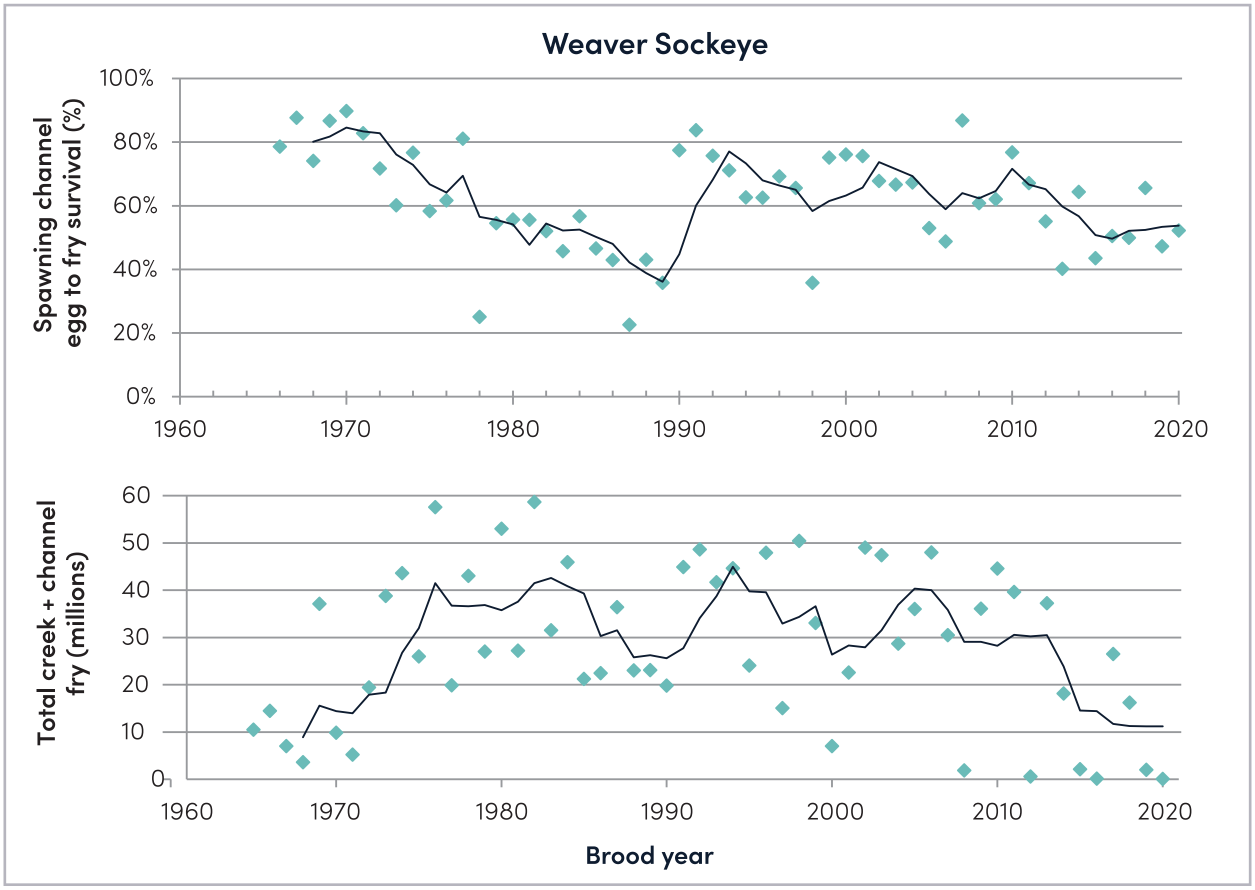



**Figure 12:** Weaver Channel egg-to-fry survival (%) (top); and total Weaver Creek + channel fry production (bottom) with 4 year moving averages, brood years 1965 to 2020.

## GATES CREEK SPAWNING CHANNEL

The Gates Creek spawning channel, built by the IPSFC in 1967-68, was intended to improve sockeye production which had declined due to degraded habitat in Gates Creek caused by logging and development. The channel had a creek intake and settling basin, a polyethylene liner to prevent leakage and a diesel pumped water supply from Anderson Lake to prevent the formation of frazzle ice (Cooper 1977).

Adult spawners are diverted into the channel by means of a weir which is operated so as to allow a portion of the escapement to remain in the creek. Final enumeration and sampling of channel spawners is by deadpitch, and visual counts are used to estimate spawners in the creek. There have been concerns in some years that spawners migrated through the channel intake and back into the creek. Fry production from the spawning channel was estimated by a rotating 5 percent fry splitter.

Egg-to-fry survival in the Gates spawning channel was initially in the 40 to 80 percent range. Documentation of the decline and subsequent increase in survival after 1990 was not available. Survival declined again in the late 2000s (Fig. 13). An inspection in 2008 found more 4-6 inch gravel than was considered optimum. Remedial work in 2008 and 2009 replaced large cobble and boulders with smaller spawning gravel. Hydraulic sampling found a 2.4-fold increase in egg survival to the eyed stage between treated and untreated areas (Northern St'at'imc Fisheries 2009). The channel was also re-graded to increase slope to improve self-cleaning of the gravel, which would simplify channel operations without gravel cleaning. Egg-to-fry survival was expected to be lower, in the 20 to 30 percent range over the long term without frequent gravel cleaning, but would not be impacted by floods that in some years impact natural production in the creek (Matt Foy pers. comm.).

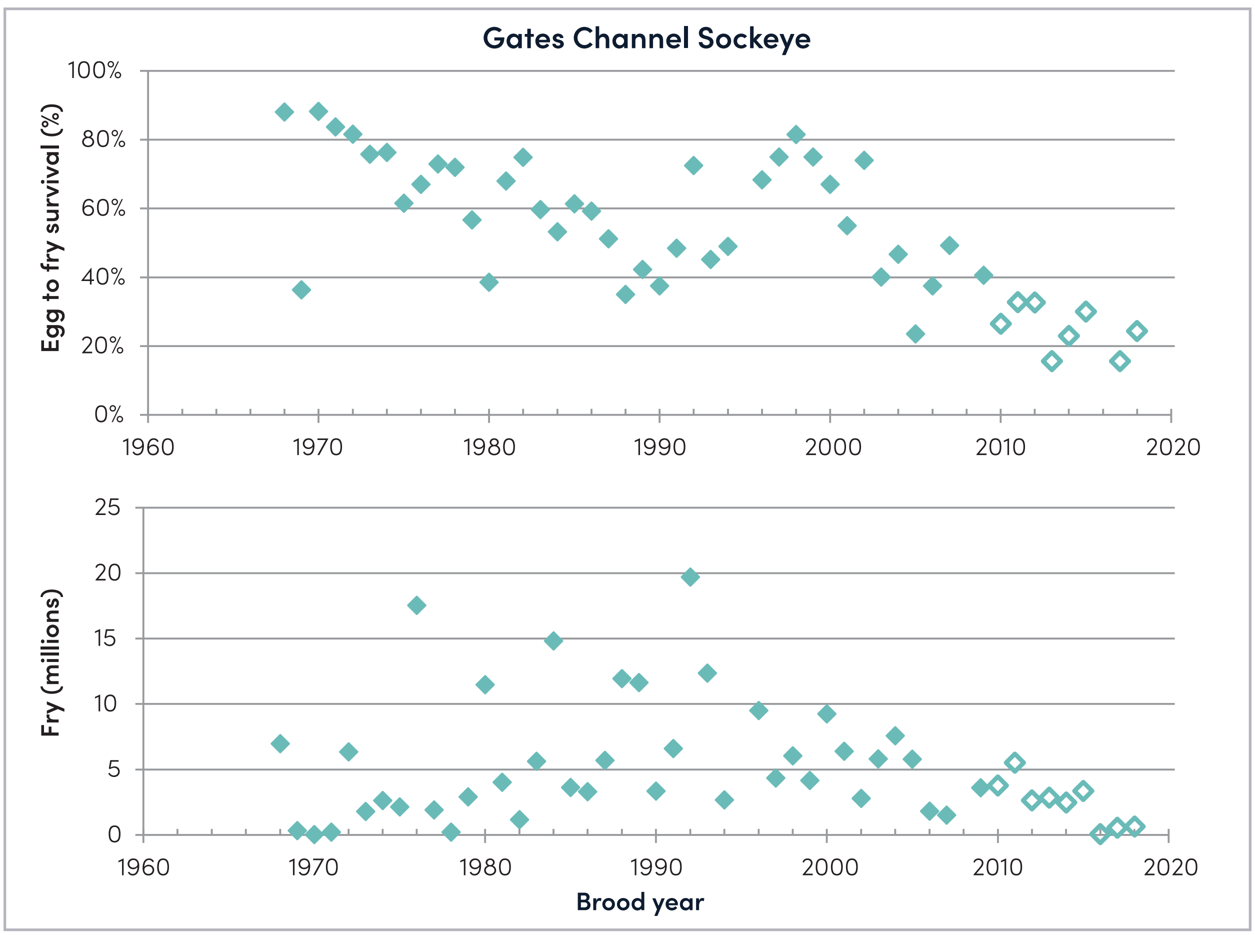



**Figure 13:** Gates spawning channel sockeye egg-to-fry survival (%) (top); and fry production (millions) (bottom), brood years 1969 to 2018. Post remedial years are indicated by hollow markers.

Egg-to-fry survival did not increase following the remedial work. Post remedial years are indicated in Figure 13 (previous page) by hollow markers. Lower fry production in recent years is a result of the expected lower egg-to-fry survivals and low spawning escapements.

Gates channel has only been filled to capacity in eight of its first 48 operational years not including 2008 and 2016 for which no spawner counts or egg deposition estimates are available.

Gates channel does not appear to have exceeded its spawning capacity. Egg-to-fry survival exhibits the usual decline with increasing egg density but fry production has linearly increased ($p<0.01$) up to the higher observed densities. Egg-to-fry survival in the post remedial years, indicated by the hollow markers, is lower than for the earlier years of operation, as was expected (Fig. 14).

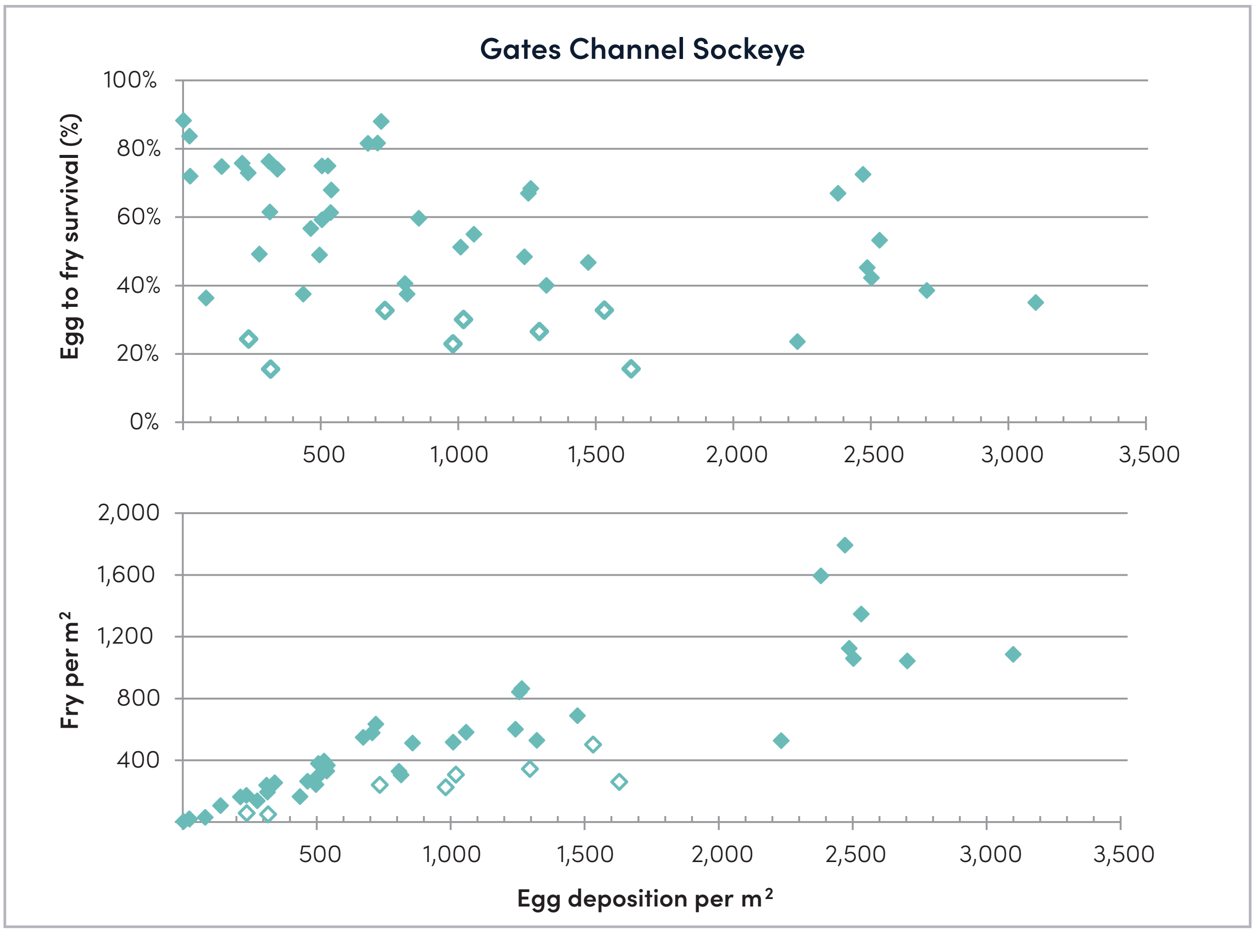



**Figure 14:** Gates spawning channel sockeye egg-to-fry survival (%) (top); and fry production per square metre versus egg deposition per square metre (bottom). Post remedial years are indicated by hollow markers.

Natural fry production from Gates Creek was estimated for the 1968 to 1984 brood years by enumeration and sampling of spawners to calculate egg deposition to which a standard egg-to-fry survival of 15 percent was applied (Cooper 1977, Rosberg et al. 1986). Fry enumeration programs in the 2010s have estimated natural production from the creek by subtracting channel production from total system estimates and found egg-to-fry survival in the creek to be at or above the assumed 15 percent (Lingard et al. 2013) (Fig. 15).

Due to operational difficulties and lower egg-to-fry survivals from the spawning channel, as well as information that larger escapements to the creek appeared to be maintaining the overall system production of fry, the Gates spawning channel has not been operated since the 2019 brood.

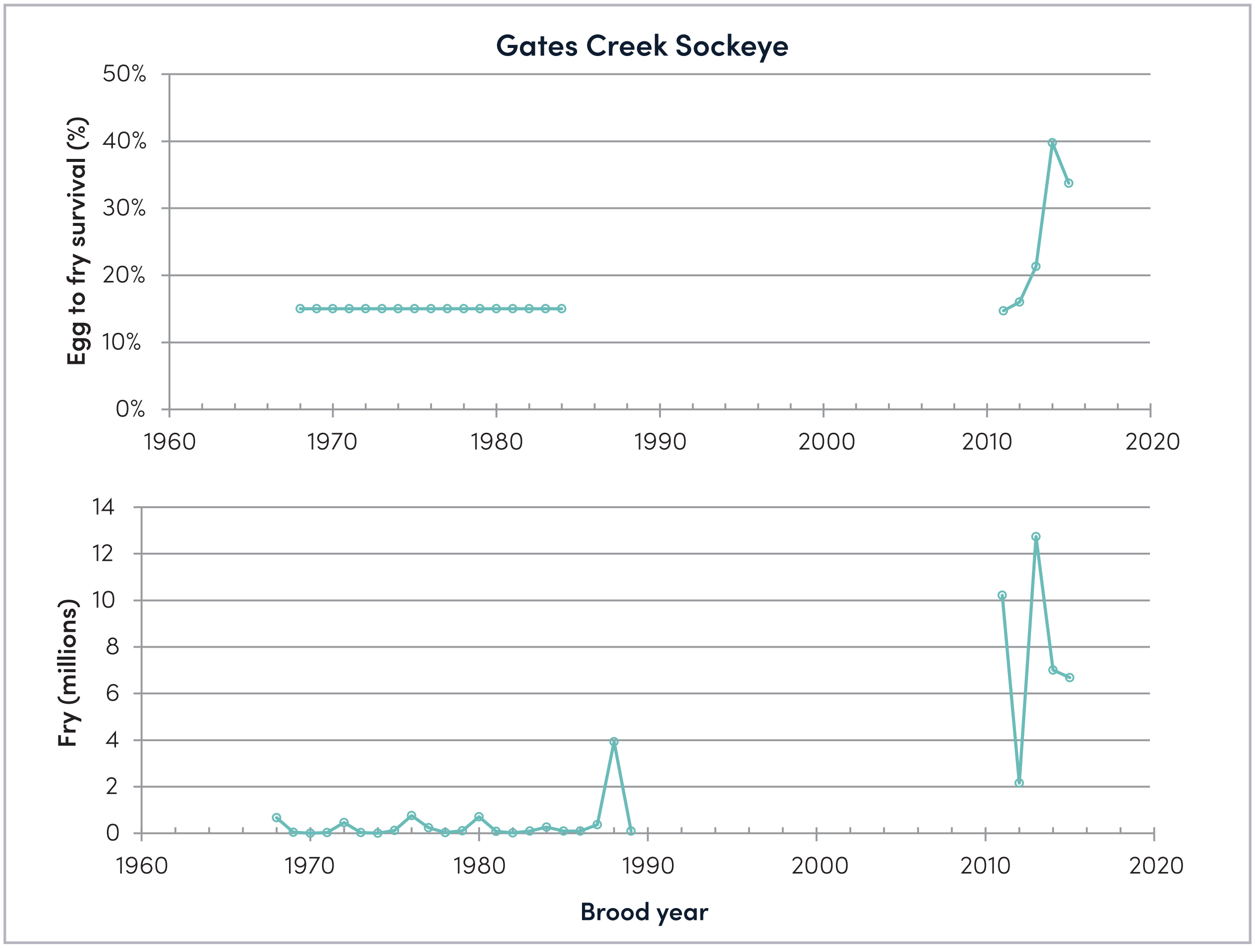



**Figure 15:** Gates Creek sockeye egg-to-fry survival (%) (top); and fry production (millions) (bottom) for brood years 1968 to 1984 (15% egg-to-fry survival is assumed, no fry enumeration) and brood years 2011 to 2018 (estimated by fry enumeration).

### Adult Production from the Gates Creek System

Rosberg et al. (1986) noted that the IPSFC estimated the Gates Creek natural spawning areas historically supported 150,000 sockeye but by the time the Gates spawning channel was built the natural system had deteriorated to where only 10,000 sockeye could be accommodated.

Cooper (1977) provides returns by brood year that show a cyclic pattern. Prior to channel returns, up to 100,000 adults returned in dominant years while one-third of the years had fewer than 1,000 returns, and one-third of the years had between 1,000 and 10,000 (Fig. 16).

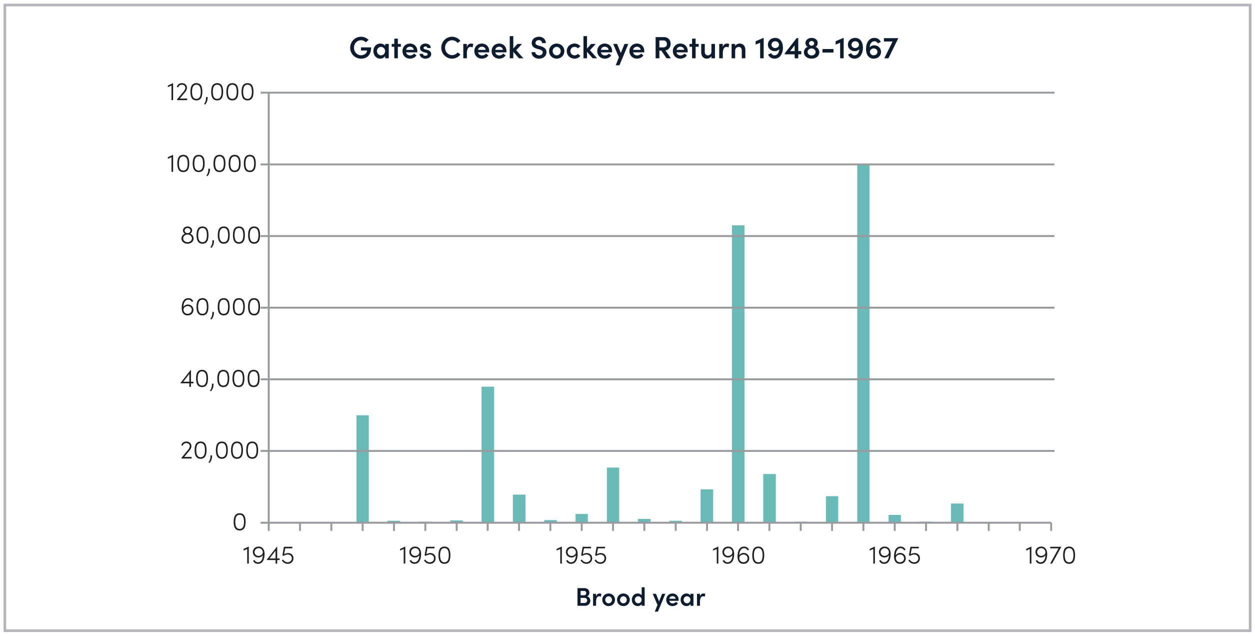



**Figure 16:** Gates Creek sockeye returns by brood year, 1948 to 1967 (data source: Cooper 1977).

Total escapement and catch by return year from 1950 to 2020 is shown in Figure 17. Since 1976, the first year of four-year old spawning channel returns, the total return has averaged 52,358 sockeye. Annual returns are significantly larger (<.005) than the brood year returns reported by Cooper (1977).

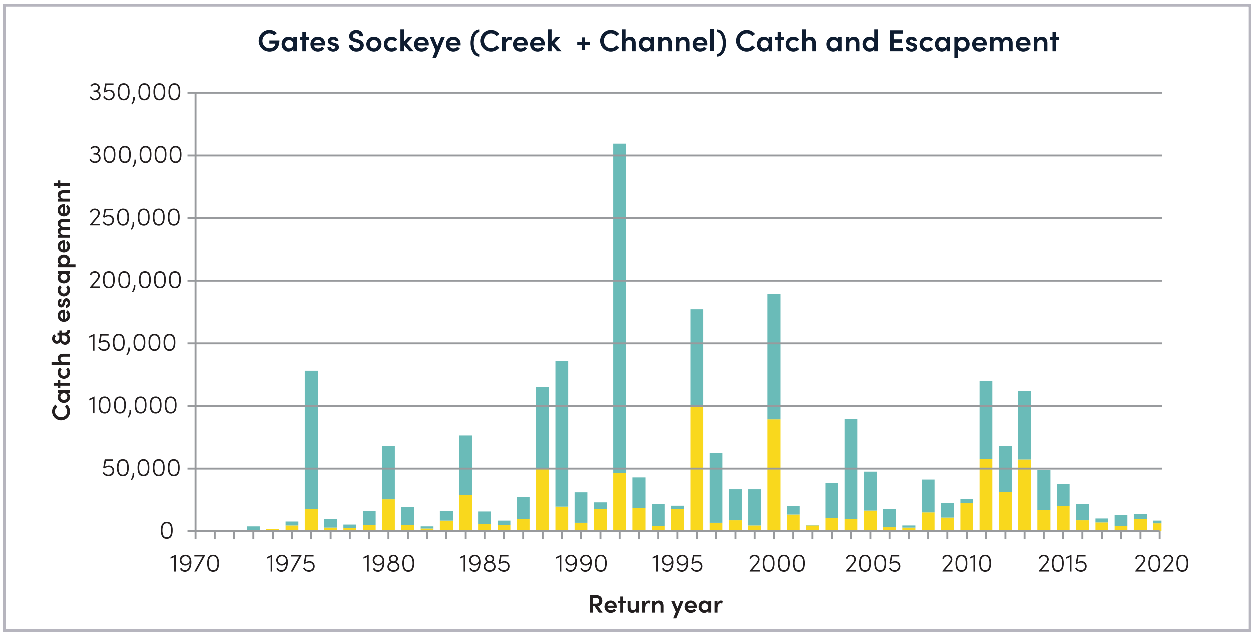



**Figure 17:** Gates sockeye (creek + channel) catch and escapement, catch (teal) over escapement (yellow), return years 1973 to 2020 (data source: NuSEDS and DFO Stock Assessment Division).

Adult recruits per spawner for Gates sockeye have a long term average of 4.8 but the recent six years have had an unprecedented string of rates below the replacement value of 1.0 (Fig. 18). The Gates channel has not operated since the summer of 2019.

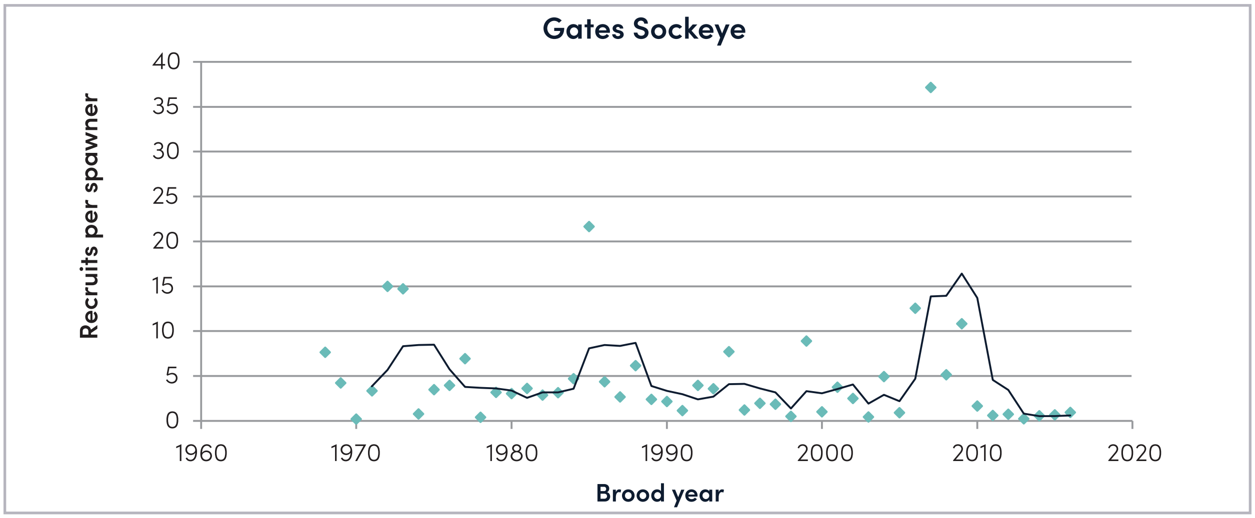



**Figure 18:** Gates adult recruits per spawner, brood years 1968 to 2016 with 4 year moving averages (data source: DFO Stock Assessment Division).

## NADINA RIVER SPAWNING CHANNEL

The Nadina River spawning channel was built by the IPSFC in 1973 with a design capacity of 14,450 females to increase production of the late Nadina sockeye stock. Earlier studies had found that only four percent of the rearing capacity in Francois Lake was utilized, the late Nadina run was limited by available spawning area, and environmental conditions were favourable for construction of a spawning channel (Rosberg et al. 1986).

*Nadina Spawning Channel. Photos by: Doug Lofthouse*

The Nadina channel is lake fed with a surface intake and a secondary pipeline to draw water from a 30 foot depth in Nadina Lake for temperature control. A detailed description of the channel is given by Cooper (1977).

The channel is located beside the upper reach of the Nadina River spawning grounds. Small numbers of adults may migrate past the channel to spawn in Glacier Creek. Use of a temporary weir to divert adults into the channel was discontinued in 2011. In most years, fish are counted into the channel. Adults were allowed unrestricted entry and estimated visually in the channel in 2018 due to lack of crew access during the Nadina Lake forest fire, and in 2019 due to concerns about stress on fish from the Big Bar Slide. In years that the channel is not filled to capacity spawners appear to prefer the top and middle legs of the channel. Spawner counts, sex ratio and sampling are provided by visual counts and deadpitch.

In recent decades, spawners have been subject to a locally expanding grizzly bear population that harvests some adult sockeye from the channel, but the operator considers the effect not too significant with the bears largely taking carcasses.

A rotating cone 5 percent sampler is used to enumerate fry from the channel. Fry production and egg-to-fry survival have averaged 6.9 million and 45 percent respectively over the 1973 to 2020 brood years. The high-low pattern of fry production reflects the alternating pattern of large and small escapements and egg deposition in the channel (Fig. 19)

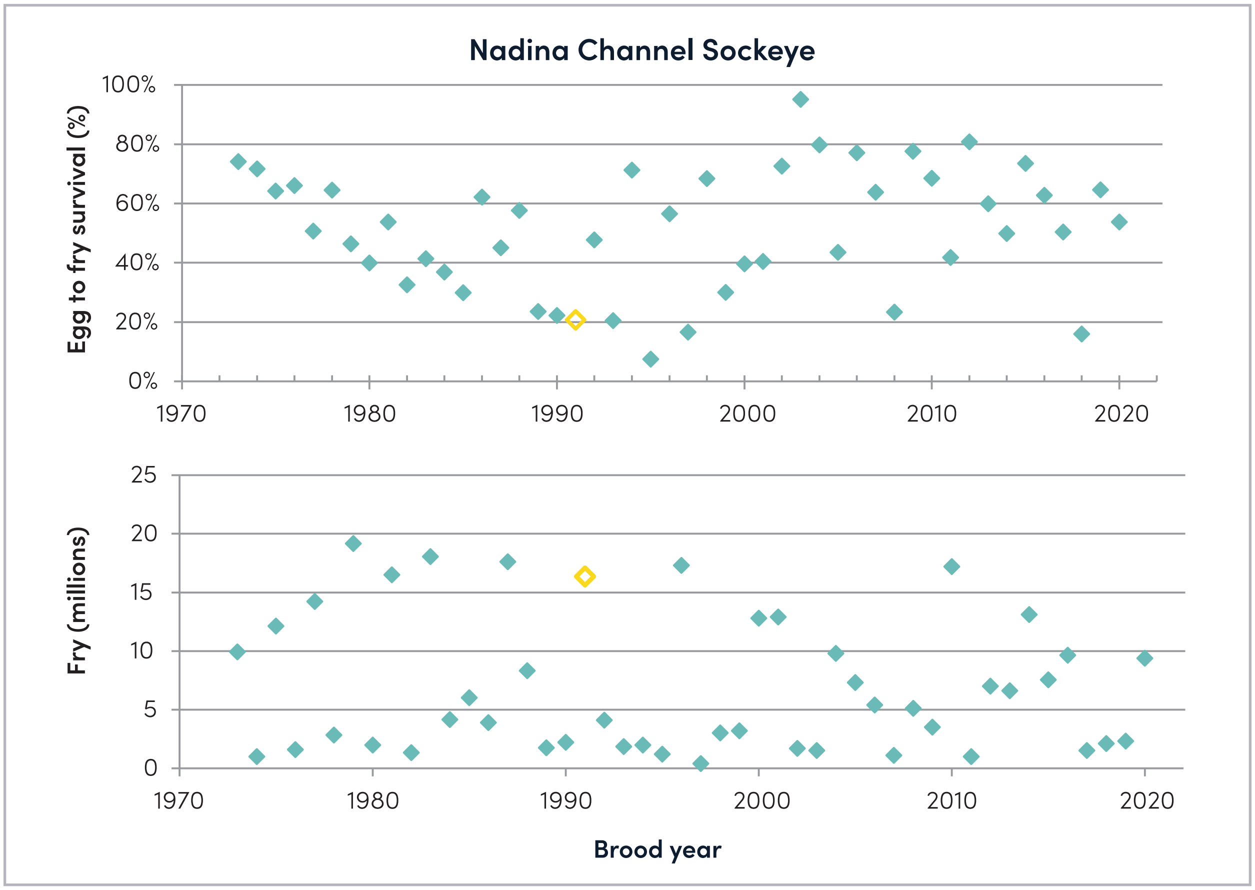



**Figure 19:** Nadina spawning channel egg-to-fry survival (%) (top); and fry production (millions) (bottom), brood years 1973 to 2020. Brood year 1991 with high loading density indicated by yellow hollow marker.

Figure 20 suggests maximum fry production may occur at egg depositions approaching 2,500 eggs per square metre. In 1991, the spawning channel was loaded at twice the normal spawning density, indicated by a hollow marker (Figures 19 and 20). Egg-to-fry survival of the 1991 brood was subsequently low at 21 percent, but fry production remained high at 902 fry per square metre, similar to years with egg densities around 2,000 eggs per square metre.

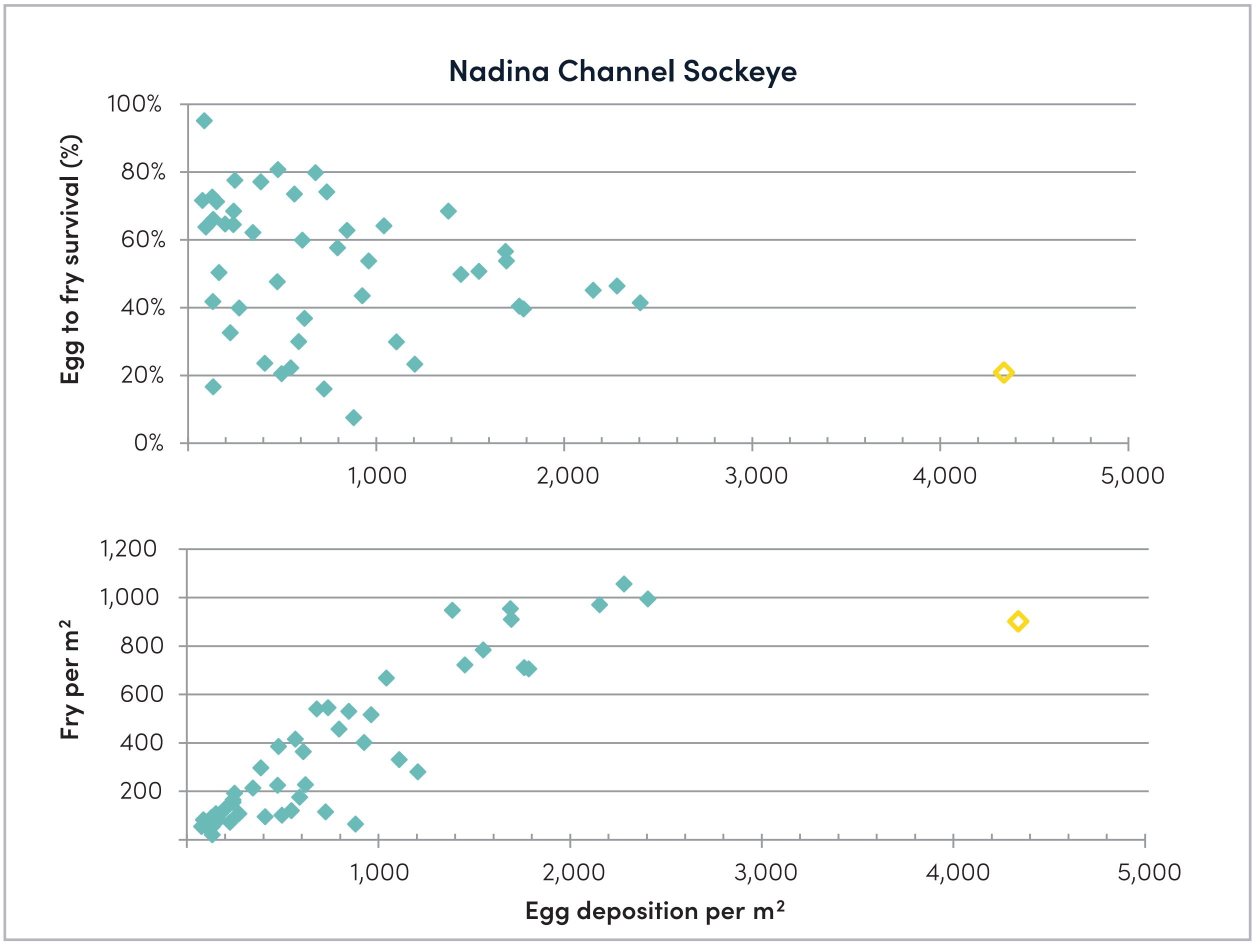



**Figure 20:** Nadina spawning channel egg-to-fry survival (%) (top); and fry production per square metre versus egg deposition per square metre (bottom). Brood year 1991 with high loading density indicated by yellow hollow marker.

High water temperature and disease have contributed to elevated prespawn mortality which has occurred in years of both high and low spawning densities. In 1961, 86 percent of females in the river are reported to have died prematurely due to high water temperatures in the 20 to 20.5 degree C range.

The first recorded occurrence of *Ichthyophthirius multifiliis* (Ich) related PSM was in 1979 with losses of 45 percent in the channel and 19 percent in the river. Prior to 1979, riverine losses had averaged 3.8 percent and from 1973 to 1985 channel losses averaged 4 percent (Rosberg et al. 1986). The first recorded occurrence of *Parvicapsula* was in 2001 in combination with Ich.

Figure 21 shows elevated PSM levels of 20 percent or more have occurred in the channel in 10 of the 25 years from 1994 to 2018. There is a weak but not significant (p>0.10) correlation between PSM and the number of adult spawners entering the channel. There is also a weak but not significant negative correlation (p>0.10) between egg-to-fry survival and the incidence of PSM. As a precaution, adult loading densities in the channel have been lowered in some recent years.

Fry production in the Nadina River has not been enumerated. Estimates of wild fry production by the IPSFC for brood years 1973 to 1984 were based on a spawning density/recruitment relationship to which a single year of hydraulic sampling data was applied (Cooper 1977, Rosberg et al. 1986).

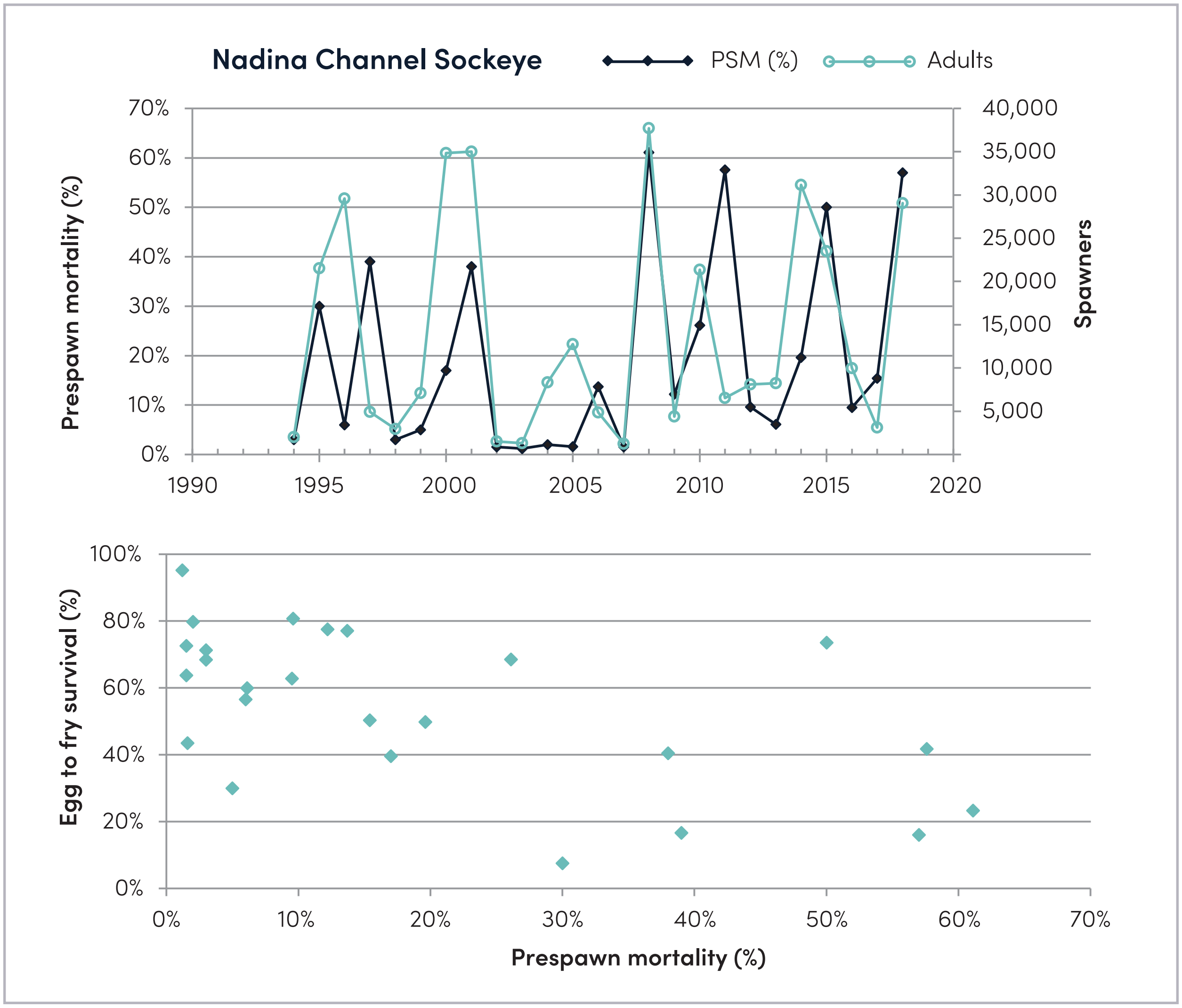



**Figure 21:** Nadina channel prespawn mortality (black line) & adult spawners (blue line) (top); and egg-to-fry survival (%) versus prespawn mortality (%) (bottom), 1994 to 2018 (data from DFO Nadina channel files).

### Adult Production from the Nadina River System

Late run Nadina sockeye returns averaged 82,360 fish from 1978 to 2020. Pre-channel escapement averaging 6,222 between 1950 and 1972, has increased to 25,774. The apparent negative catch in 2020 is the result of subtracting escapement from the total return estimate and illustrates the inherent inaccuracy in estimating the abundance of small stocks in large mixed stock fisheries. Figure 22 shows the cyclic dominance pattern of late run Nadina sockeye returns which have a slight increasing but insignificant trend ($p>0.50$). In contrast to Figure 22, adult recruits per spawner by brood year show a decreasing trend in the 4 year moving average (Fig. 23). Recruits per spawner for four of the recent six brood years have been at or below the replacement rate of 1.0.

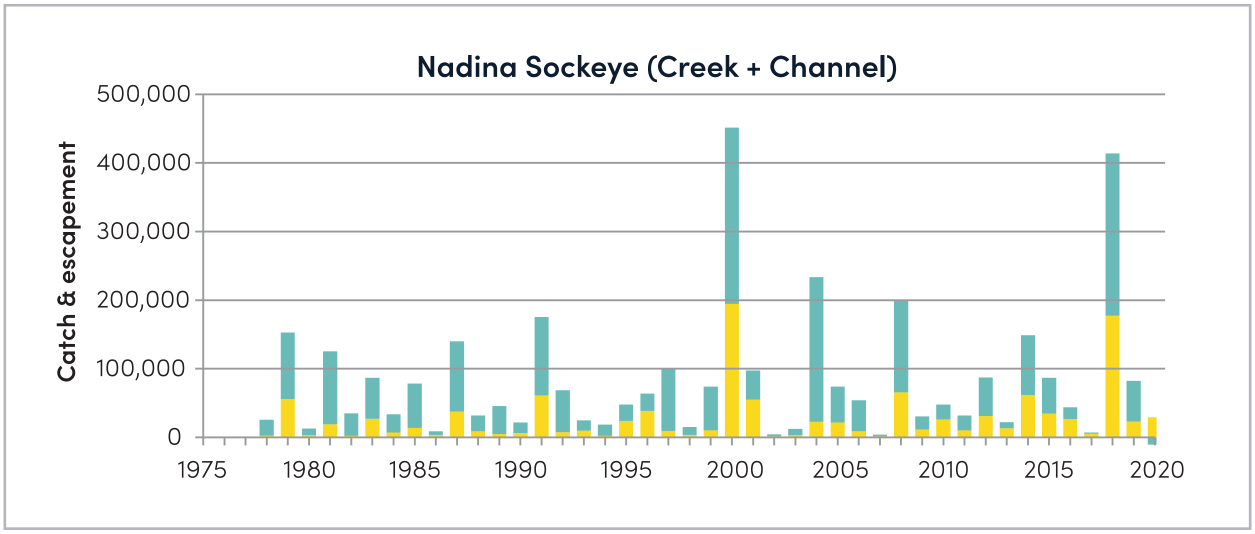



**Figure 22:** Nadina sockeye (creek + channel) catch and escapement, catch (blue) over escapement (yellow), return years 1978 to 2020 (data source: NuSEDS and DFO Stock Assessment Division).

Total river plus channel fry production has not been used to examine in-lake plus marine survival because the high proportion of river spawners in recent years and the assumed fry productivity of the river based on only one hydraulic sampling point were considered to make further analysis too uncertain.

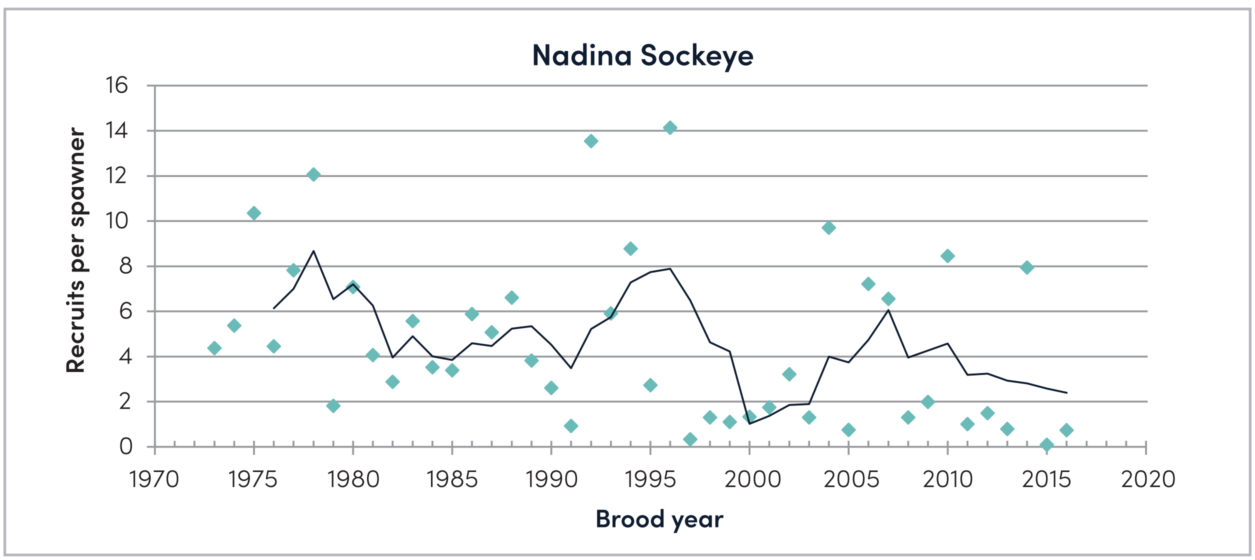



**Figure 23:** Nadina sockeye recruits per spawner and 4 year moving average, brood years 1973 to 2016.

The decreasing trend in recruits per spawner is influenced by larger percentages of adult escapements spawning in the river with lower egg-to-fry survival rates. Prior to 1996, approximately 90 percent of the late run escapement spawned in the channel, but from 1996 onwards the percentage decreased to an average of 54 percent. The change in spawning location would reduce total fry production and perhaps recruits per spawner by one quarter. Excluding the years 2008 and 2018 which had very large escapements, there does not appear to be a density effect that causes more fish to spawn in the river (Fig. 24). Use of the temporary fence to divert fish into the channel was discontinued in 2011 (Brad Thompson pers. comm.) but the change in behaviour began 14 years before the diversion fence was discontinued. The reason for increased spawning in the river is unknown.

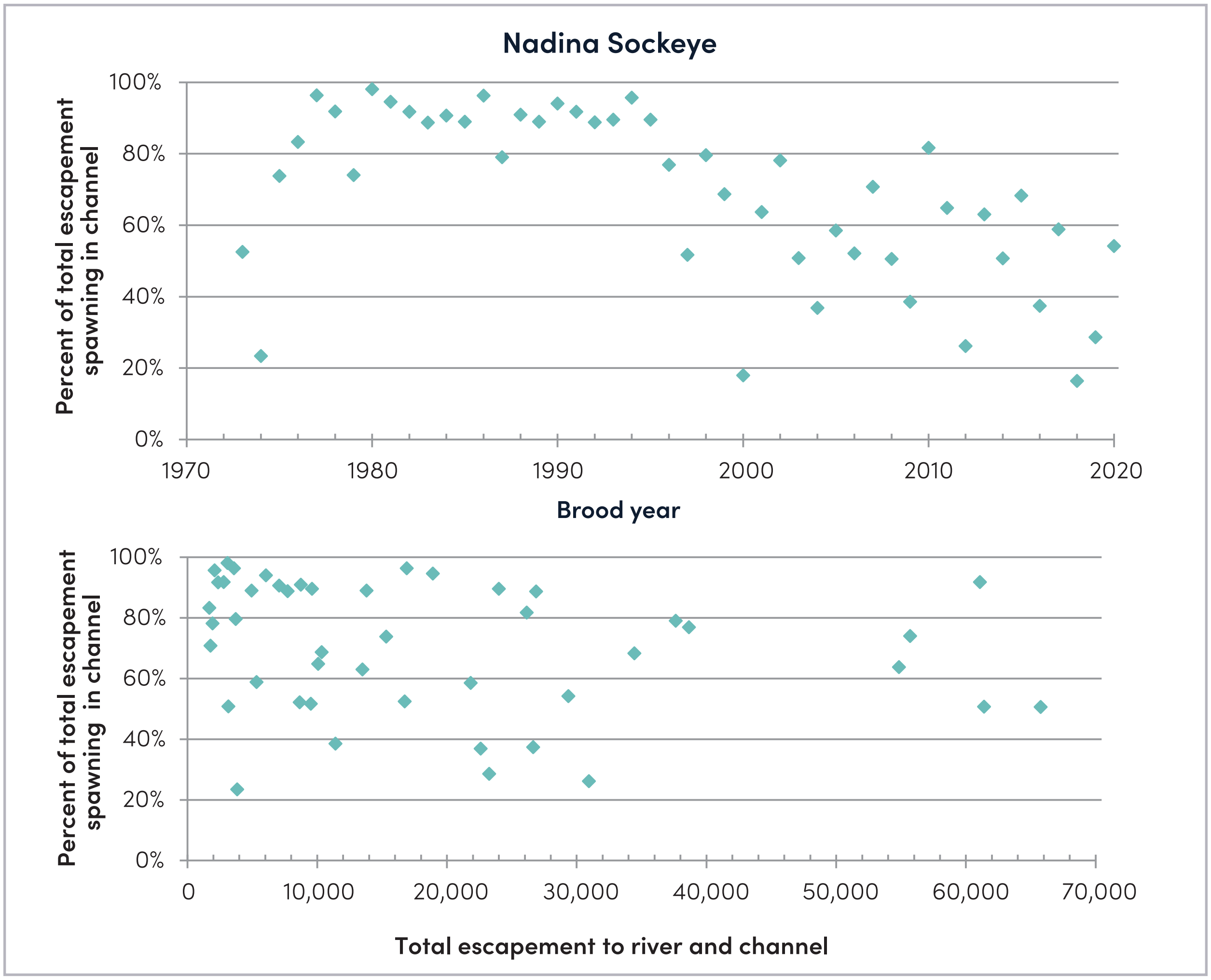



**Figure 24:** Nadina sockeye, percent of total river plus channel escapement spawning in the channel for brood years 1973 to 2020 (top); and percent of total river plus channel escapement spawning in the channel versus total river plus channel escapement (bottom) not including 2008 and 2018 escapements beyond the scale of the graph.

# BABINE LAKE DEVELOPMENT PROJECT

The Babine Lake Development Project was built in the mid 1960s and early 1970s to increase production of sockeye salmon from Babine Lake on the Skeena River system.

After a long period of decline in the Skeena salmon fishery, followed by a land slide on the Babine River in 1951, which seriously depressed two successive brood years of Babine sockeye, the Skeena Salmon Management Committee was formed in 1954 to improve management and increase yields of Skeena River salmon stocks. Rehabilitation of the Babine lake sockeye run was considered paramount (McDonald, 1963).

Studies by the Fisheries Research Board of Canada determined the rearing capacity of the main basin of Babine Lake to be underutilized (Johnson 1956, 1958, MS 1961) and that it could accommodate increased fry production. Based on early experience at the Big Qualicum project, river flow control was expected to increase egg-to-fry survival to the 25 to 35 percent range (Fisheries Research Board of Canada and Department of Fisheries 1965, Heskin 1967). Additional fry production from spawning channels was selected over hatcheries because the viability of spawning channel fry was expected to be higher than that of hatchery fry and comparable to naturally produced fry (Mead and Woodall 1968).

Two Babine Lake tributaries, Fulton River and Pinkut Creek were selected for development of spawning channels and river flow control works which collectively became known as the Babine Lake Development Project (BLDP).

## PRESPAWN MORTALITY AT THE BABINE LAKE DEVELOPMENT PROJECT

Prespawn mortality occurs naturally among spawning sockeye throughout BC, typically around 10 percent or less with some stocks like Gates Creek sockeye having slightly higher background levels. Elevated levels of PSM have been known to occur due to stressors such as parasites, viral disease, or high temperatures and can have a significant effect on production from the affected brood year. The IPSFC (1962) reported adverse water temperatures causing high numbers of female sockeye in 1961 to die unspawned: Bowron (60%), Nadina early run (86%), Chilko (31%), Horsefly (62%), Stellako (31%), Raft (25%) and Birkenhead (35%). Williams et al. (1977) reported PSM rates in the range of 40-65 percent in the dominant years of the Horsefly, McKinley Creek and Mitchell sockeye stocks in the 1960s, also noting late timing and below average spawning ground temperatures in 1973 were favourable factors which limited the mortality (to lower rates in the 19-27% range).

Elevated PSM first occurred at the BLDP at Fulton in 1994 and 1995, due to high levels of *Ichthyophthirius multifiliis* (Ich). Traxler et al. (1998) noted this was the first report of an epizootic of *Ichthyophthiriasis* in wild spawning salmon and likely came from resident fish because several species were found with light infections. The parasite was also found in wild sockeye stocks within the watershed (Morrison River, Pierre Creek, and Babine River) (Wood et al. 1998). A disease monitoring program was established in 1995 and an additional parasite, *Loma salmonae* (Loma) was first detected in 1997. Loma is a well known pathogen of ocean-farmed salmon in the Pacific Northwest, contracted during ocean migration and returning to spawning grounds with adult sockeye, it can be found at some level within the monitored BLDP stocks every year (D. Lofthouse pers. comm.).

Prior to 1994, PSM at the BLDP typically ranged below 10 percent (Fig. 25). The operational response to elevated PSM has been to reload with surplus spawners to maintain egg deposition, minimize channel loading time to reduce crowding behind the weirs and transmission of parasites, reduce spawning densities when the monitoring program indicates high levels of parasites, and to reduce water temperatures using the deep lake intake at Pinkut. Terminal in-lake ESSR fisheries also reduce adult crowding behind fences. There is no significant correlation of PSM percent between the Fulton and Pinkut sockeye stocks ($p>0.10$).

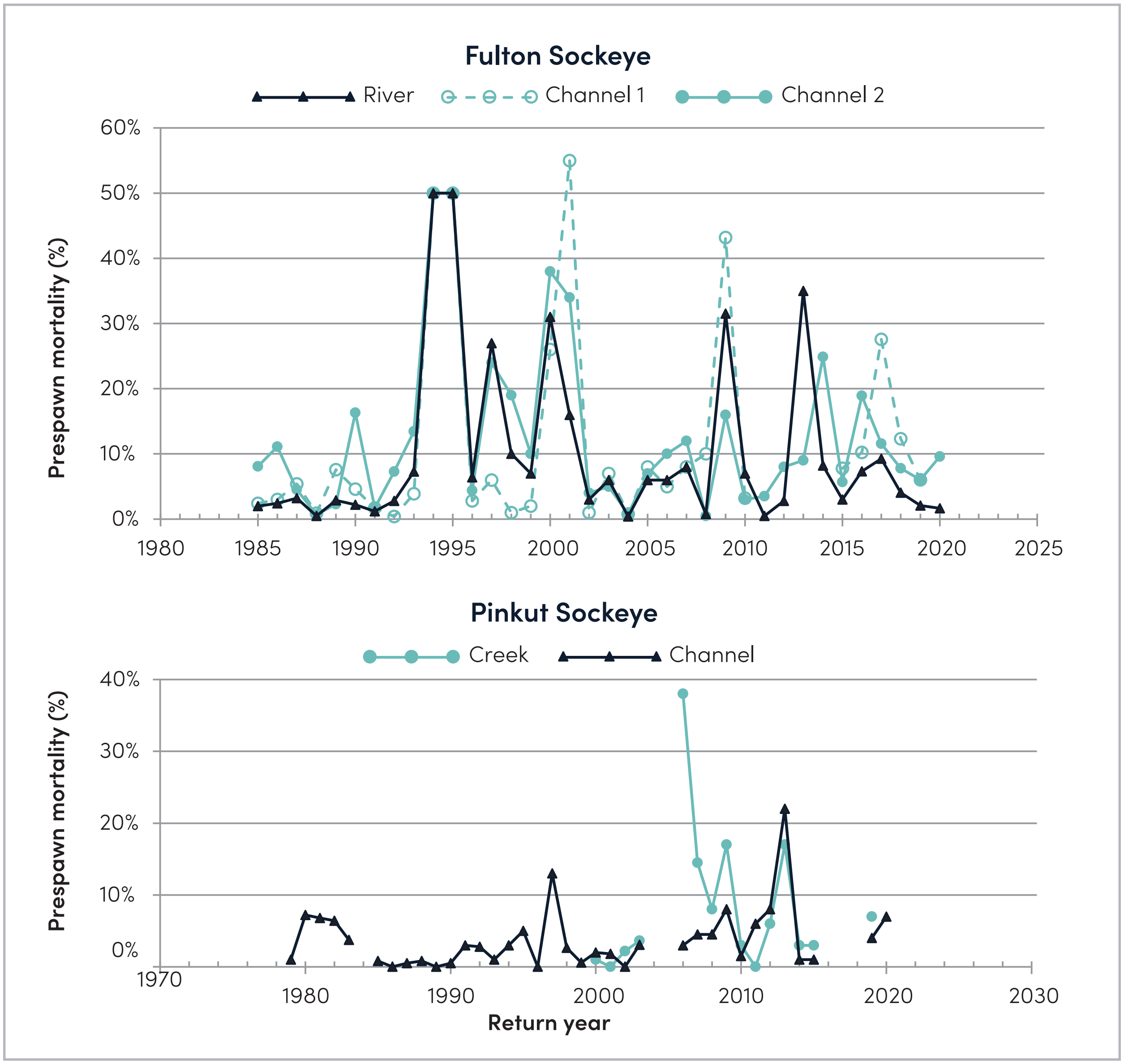



**Figure 25:** Prespawn mortality (%) in Fulton River (dark blue solid line), channel 1 (dashed teal line), and channel 2 (solid teal line) (top), 1985 to 2020. Pinkut Creek (teal line) 2000 to 2019 and Pinkut channel (dark blue line), 1975 to 2020 (bottom).

# FULTON RIVER PROJECT

The Fulton River project consists of two spawning channels, a 40 foot high dam and regulating works for river flow control and water supply to spawning channel 2, and a continuous weir below channel 2 and the main section of river spawning grounds for adult and fry enumeration. Detailed descriptions of the project are given in Heskin (1967) and Ginetz (1977).

## Fulton River Flow Control

The Fulton Dam was completed in 1968 and provides control of flow for spawning and incubation. Flow control did not significantly change egg-to-fry survival ($p>0.05$), averaging 21 percent and 18 percent in pre- and post-flow control periods respectively. Pre-flow control years in Fulton River are indicated by hollow markers (Fig. 26 and Fig 27). Fry production has increased from averages of 31 million to 39 million fry in pre- and post-flow control periods due to larger spawning escapements and increased egg deposition.

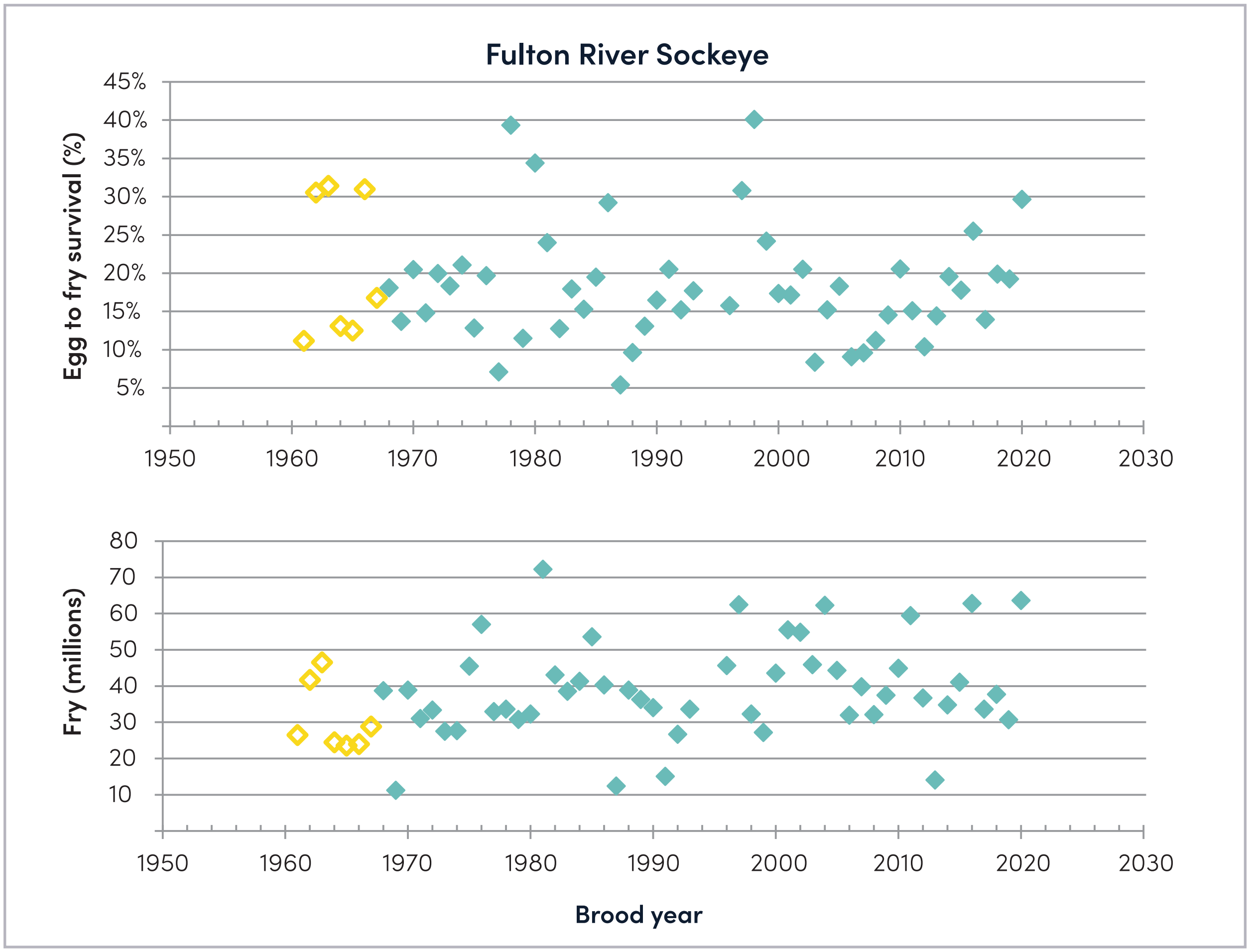



**Figure 26:** Fulton River sockeye egg-to-fry survival (%) (top) and fry production (millions) (bottom), brood years 1961 to 2020. Pre-flow control years in Fulton River are indicated by hollow yellow markers.

In 2000, the spawning density target for Fulton River above the weir was doubled from 50,000 to 100,000 females (100,000 to 200,000 spawners) to compensate for anticipated prespawn mortality caused by the external parasite Ich. PSM losses of over 50 percent (visual estimates) had occurred in 1994 and 1995 and was beginning to show signs of elevation in 2000. Surplus escapement was available below the river weir, and the previous target was based on the estimated area of good quality spawning gravel when in fact Fulton River has additional areas of less preferred spawning gravel that could accommodate additional spawners if necessary. The escapement target above the weir has remained at 200,000 spawners and fry production from the river has averaged 43 million fry since the year 2000.

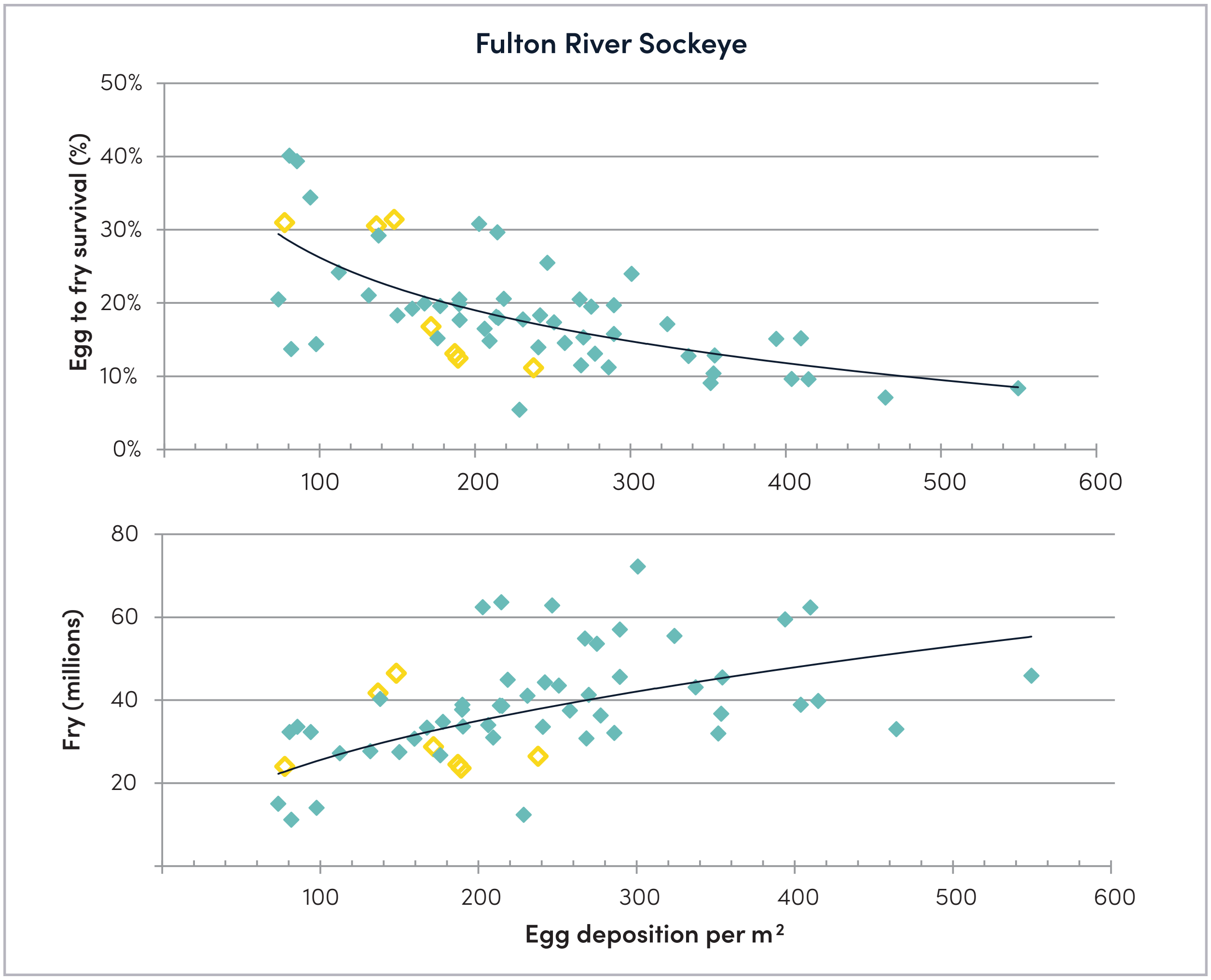



**Figure 27:** Fulton River sockeye egg-to-fry survival (%) (top) versus egg deposition (y =-0.104ln(x) + 0.7405 p<0.01) and fry production (millions) versus egg deposition (millions) (y = 3.1878x0.4523 p<0.01) (bottom). Pre-flow control years in Fulton River are indicated by yellow hollow markers.

Egg-to-fry survival in Fulton River shows a logarithmic decline (p<0.05) with increasing egg deposition while fry production increases at a declining rate with increasing egg deposition (Fig. 27). Egg deposition in the river is not presented as eggs per square metre because nominal estimates of spawning area in Fulton River are estimates of 'good quality' spawning area preferred by adult sockeye spawners and do not include additional fringe areas that would normally receive moderate or light spawning. Hence, density estimates from Fulton River are not directly comparable to density estimates in spawning channels. Another confounding factor is that since 2015, spawning channel 1 has been operated as a side channel of the river with unrestricted spawner access and the resulting fry are included in the enumeration of river fry. Egg deposition in channel 1 is typically less than 10 percent of the total river plus channel 1 deposition and would not materially change the relationship in figure 27. The highest egg depositions in Fulton River are, allowing for the preceding discussion of spawning area, higher than those observed in spawning channels and may contribute to the non-linear relationships that were not observed in the channel data.

### Fulton Spawning Channel 1

Fulton channel 1 was the first BLDP channel, with a river intake, no settling basin, and an outflow back to the river. Fry traps at the inlet and outlet provided complete capture to monitor production of fry from the channel. Completed in 1965 too late for spawning, the channel was planted with 1.2 million eyed sockeye eggs with a resulting survival to emergence of 82 percent. In 1966-1971, adults were diverted from the river into the channel throughout the duration of the run which in 1966 resulted in over-crowding in the top end of the channel and caused wave spawning and increased egg mortality (Ginetz 1972). From 1967 onwards, intermediate fences were used to control adult distribution within the channel and prevent wave spawning (West 1978) until 1972 when it was realized that a more even distribution of spawners could be obtained by loading over a short period of time at the peak of the run (Ginetz 1977).

Egg-to-fry survival and fry production declined from 1966 to 1970. In 1971 the spawning gravel was removed, cleaned, and replaced, with a resultant return to higher rates of egg-to-fry survival. Gravel cleaning was then carried out on an annual basis by raking with a frame with foot-long steel spikes bolted to the bottom of a bulldozer bucket, referred to as the Babine rake, but was described by Ginetz (1977) as having moderate success. Unfortunately, the more effective gravel cleaner with air-water jet technology developed by the IPSFC for Fraser River channels (that came into use at the BLDP in 1977) could not be operated in channel 1 due to physical constraints (S. Barnetson pers. comm.), and channel 1 continued to be cleaned with the less effective gravel rake. Over several decades, fry production and egg-to-fry survival declined to levels similar to that of the river (Fig. 28).

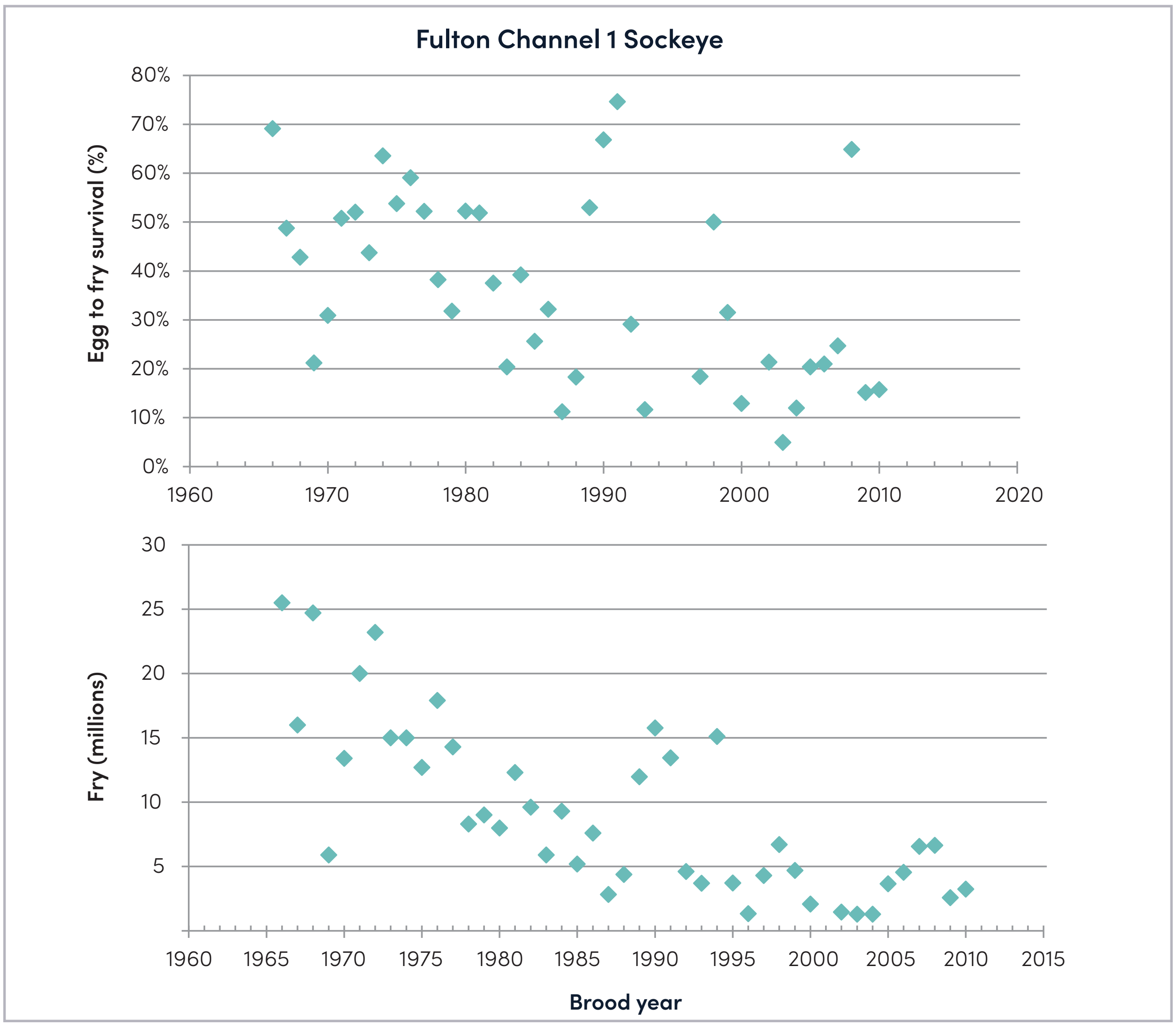



**Figure 28:** Fulton channel 1 sockeye egg-to-fry survival (%) (top) and fry production (millions) (bottom), brood years 1966 to 2010.

In 1974, spawning density in channel 1 was reduced from 1.0 to 1.25 square metres per female when it became more apparent how egg mortality was density-dependent (Ginetz 1977). Figure 29 shows a decline in egg-to-fry survival with increasing egg density in these early years, although fry production did increase at these higher spawning densities.

Egg deposition was not estimated in 1994-1996 when effective spawner estimates were confounded by high PSM caused by the Ich parasite. From 2011 to 2014 the channel was not operated due to a damaged intake. In 2001 and since 2015, the channel has been operated passively as a side channel of the river, with spawners and fry production included in the river estimates.


**Figure 29:** Fulton channel 1 sockeye egg-to-fry survival (%) (top) and fry production per square metre versus egg deposition per square metre (bottom), brood years 1966 to 2010.

## Fulton Spawning Channel 2

Fulton channel 2 is believed to be the largest artificial spawning channel in the world with capacity for approximately 120,000 adult sockeye at 1.25 square metres per female. For perspective, channel 2 is larger than the four Fraser River sockeye channels combined. Adult control structures are built into the channel to facilitate loading of adults and to control spawner density in ten separate sections of the channel. Water is supplied by a 2.7 km tunnel and pipeline from the regulating works at Fulton Lake. Provision was made when constructing the intake for the future installation of an additional deep water pipeline into Fulton Lake to supply cold water. The channel was built in two stages, the upper half becoming operational in 1969 and the lower half in 1971.

Channel 2 has a unique history. In the first cycle of operations, river fish avoided the channel 2 outflow and adult sockeye had to be physically moved into the channel or attracted by pumping water from the adjacent river into the channel. The resulting progeny have since homed to channel 2 and avoid river water unless it is mixed with water from channel 2. It has been speculated that the concrete tunnel and steel pipeline may have caused this avoidance and selective homing.

Annual production from Fulton channel 2 has averaged 74 million sockeye fry at 47 percent egg-to-fry survival but has varied widely (Fig. 30). An outbreak of the IHN virus caused low egg-to-fry survival and fry production from the 1983 brood but was not reported in Fulton channel 1 or the Pinkut channel. Garver et al. (2022) postulated the outbreak in channel 2 may have been precipitated by poor intragravel environmental conditions caused by unusually thick growth of algal mats that formed on top of the gravel surface. Garver et al. (2022) also refer to IHN being found in channel 1 and channel 2 fry in 1977 but this was not an epizootic event. Fry from the channels were being reared in hatchery tubs for growth acceleration, on a non-IHN free water supply from Fulton River, and suffered mortality due to IHN. A supplementary study to examine the presence of IHN in the Fulton system indicated the virus was enzootic in Babine stocks (Boyce 1982).

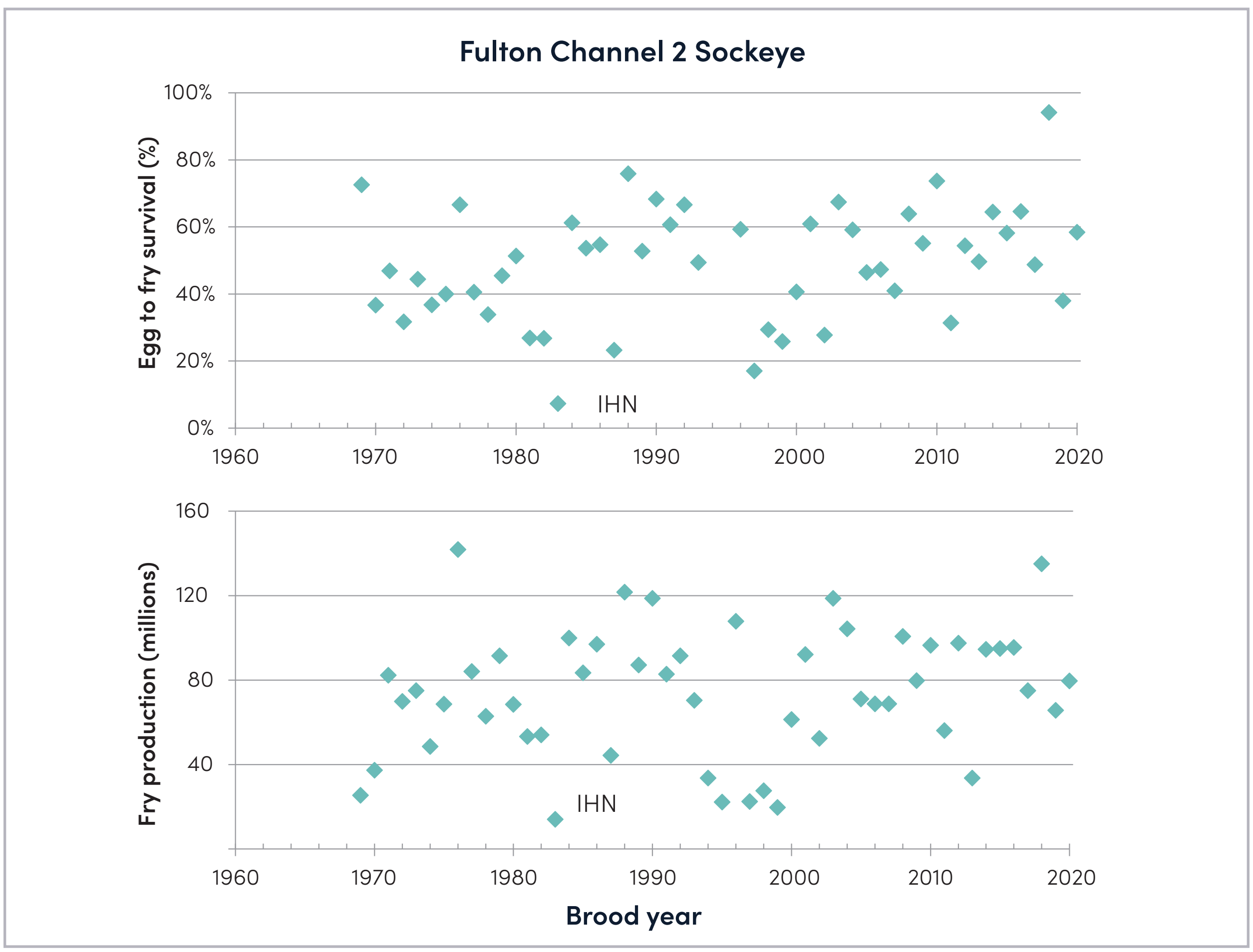



**Figure 30:** Fulton channel 2 sockeye egg-to-fry survival (%) (top) and fry production (millions) (bottom), brood years 1969 to 2020.

Survival and production can also be influenced by operational history and disease. Gravel in channel 2 is cleaned annually to prevent the accumulation of organics and silt that could decrease egg-to-fry survival. In 1977, gravel cleaning technology was improved by replacing the gravel rake with the air-water jet cleaner. In 2001, gravel in the upper legs of the channel (legs 1-12), which contained insufficient gravel in the 1.0 to 2.5 inch size range per the original gravel specifications, was replaced with a more suitable mix, and in 2017 the gravel in the remaining legs was removed, cleaned, augmented and replaced.

Historic egg deposition in channel 2 is clustered around 2,200 eggs per square metre, approximately equivalent to the current spawning density target of 1.25 square metres per female. Figure 31 indicates egg-to-fry survival and fry production decrease above 2,500 eggs per square metre, equivalent to 1.1 square metres per female.

Prior to the mid-1980s, spawning density in the upper sections of channel 2 was often decreased in an attempt to obtain higher egg-to-fry survival from this area with sub-optimal gravel. Figure 31 identifies the six years of highest overall egg density which were from this period and which did not, on average, result in higher fry production. Around 1986, the decision was made to maintain the target density of 1.25 females per square metre throughout the channel. A consideration for this decision was that hydraulic sampling, the only available method of monitoring egg survival in different areas of the channel, was too inaccurate to assess differences resulting from different spawning densities.

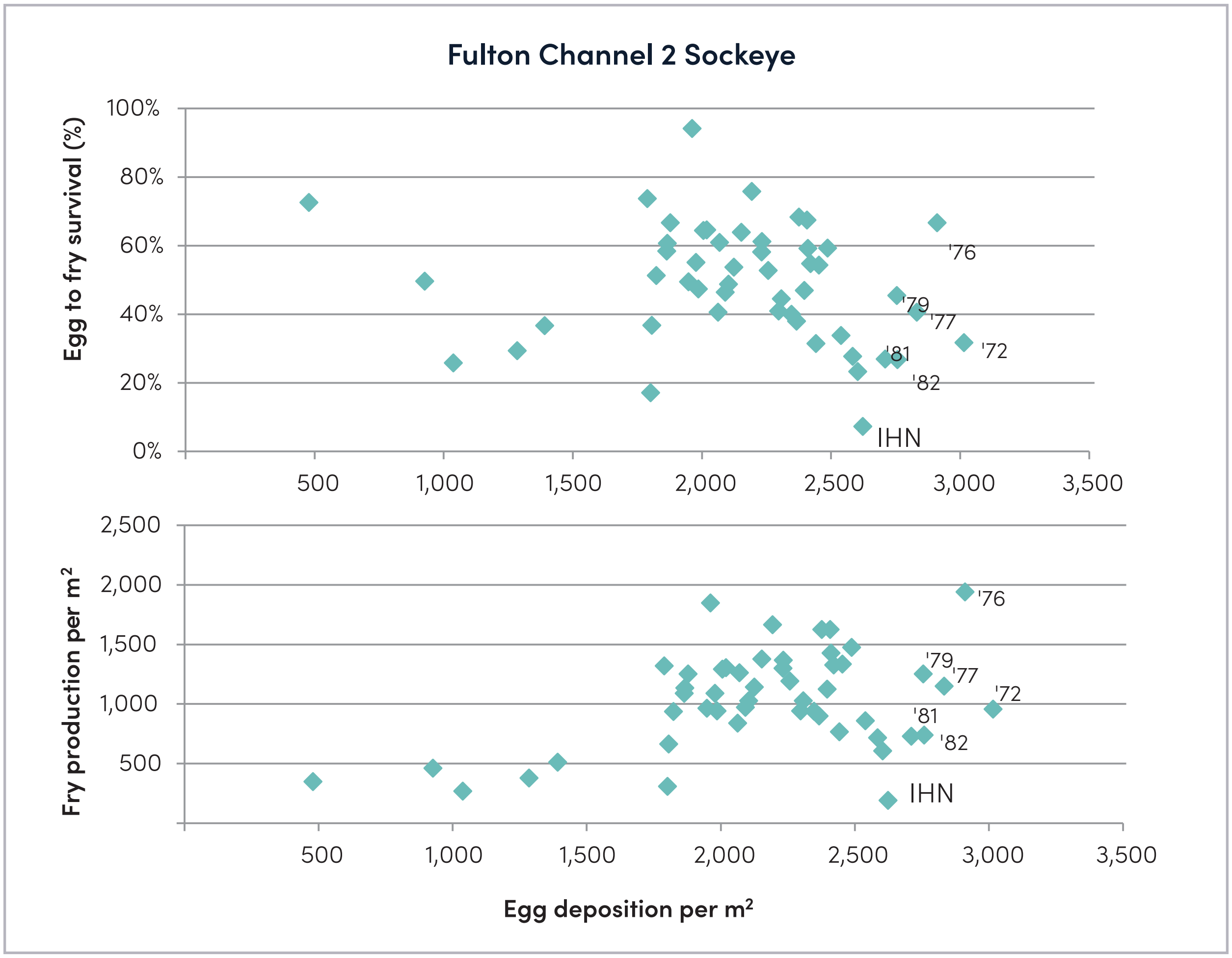



**Figure 31:** Fulton channel 2 sockeye egg-to-fry survival (%) (top) and fry production per square metre versus egg deposition per square metre (bottom), brood years 1969 to 2020. IHN indicates when outbreak of Infectious Haematopoietic Necrosis (IHN) occurred.

High PSM at the BLDP first occurred in the Fulton River and channels in 1994 and 1995. It has since occurred intermittently and is associated with elevated levels of the Ich and Loma parasites and high water temperatures. In years of elevated PSM, channel operators have to some extent and depending on the availability of surplus escapement been able to reload affected sections of the channel to maintain egg deposition.

Years of high PSM may be associated with lower egg-to-fry survival. However, reloading with fresh spawners confounds interpretation of the fry production. In brood years 2000, 2009 and 2013 which were affected by high PSM, egg-to-fry survival remained within the normal range of 40 and 55 percent, but was low in brood year 1997 (Fig. 32).

High PSM may also affect the accuracy of egg deposition and egg-to-fry survival estimates. Sampling of females for egg retention and whether they died unspawned is used to calculate egg deposition and subsequent egg-to-fry survival. In years of high PSM, estimates of female mortality must be updated by less accurate visual estimates. The highest levels of PSM were in 1994 and 1995 when it was visually estimated to exceed 50 percent. Egg deposition could not be reliably estimated and hence no estimates of egg-to fry survival were made for these years. Fry production for those years was estimated by the regular enumeration program to be approximately 400 fry per square metre, about one third of normal production.

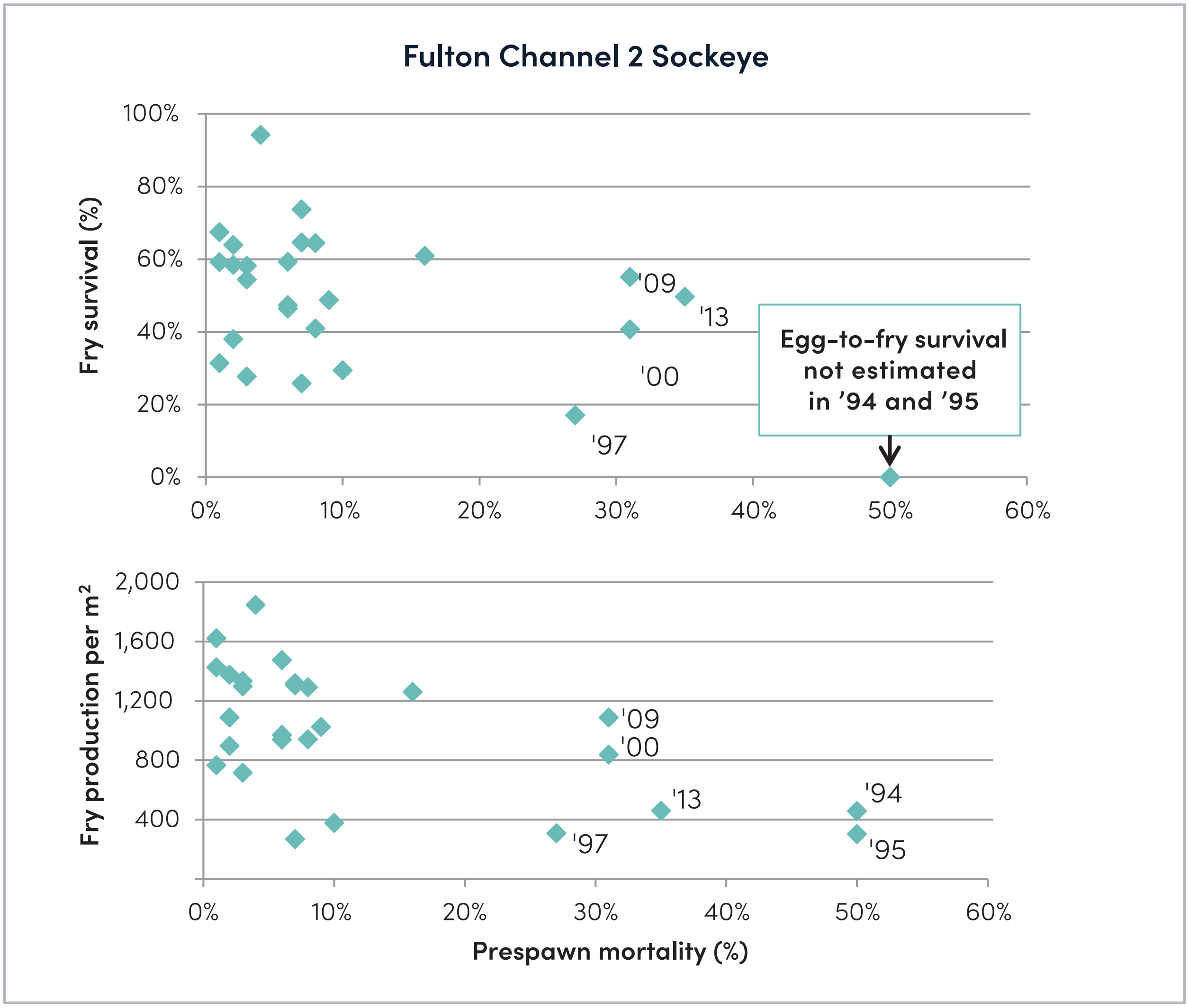



**Figure 32:** Fulton channel 2 sockeye egg-to-fry survival (%) (top) and fry production per square metre versus prespawn mortality (%) (bottom), brood years 1994 to 2020.

## PINKUT CREEK PROJECT

The Pinkut Creek project consists of one spawning channel with a settling basin, a low head weir at the outlet of Taltapin Lake for water storage to maintain spawning and incubation flows, and a regulating works and tunnel to divert river flow from above the main spawning area on Pinkut Creek to the spawning channel. A continuous weir below the spawning channel and the main spawning area of the creek provides adult control and fry enumeration for the creek and channel. Additionally, surplus spawners have been airlifted over impassible falls upstream of the main creek spawning area in 28 of the years between 1973 and 2007.

### Pinkut Creek Flow Control

Pinkut Creek flow control began in 1968 and was expected to increase egg-to-fry survival to a range of 25 to 35 percent. Pre-flow control years are indicated in Figure 33 by hollow markers. Egg-to-fry survival did increase, from a pre-flow average of 11.2 to 23.4 percent, not including the extreme high escapement pre-flow control year 1964. The trend lines in Figure 33 are not significant, but are shown to illustrate the approximate 12 percent increase in egg-to-fry survival after flow control. However, egg-to-fry survival in flow control years may also have benefitted from the channel outflow which discharges above the main spawning area of the creek and is warmed with lake water to reduce frazzle ice during very cold periods. Also, the accuracy of egg-to-fry survival estimates in the pre-flow control period is suspect, as Gintez (1977) noted the lack of accuracy in the 1963-65 egg deposition estimates and difficulties enumerating fry in 1966-67.

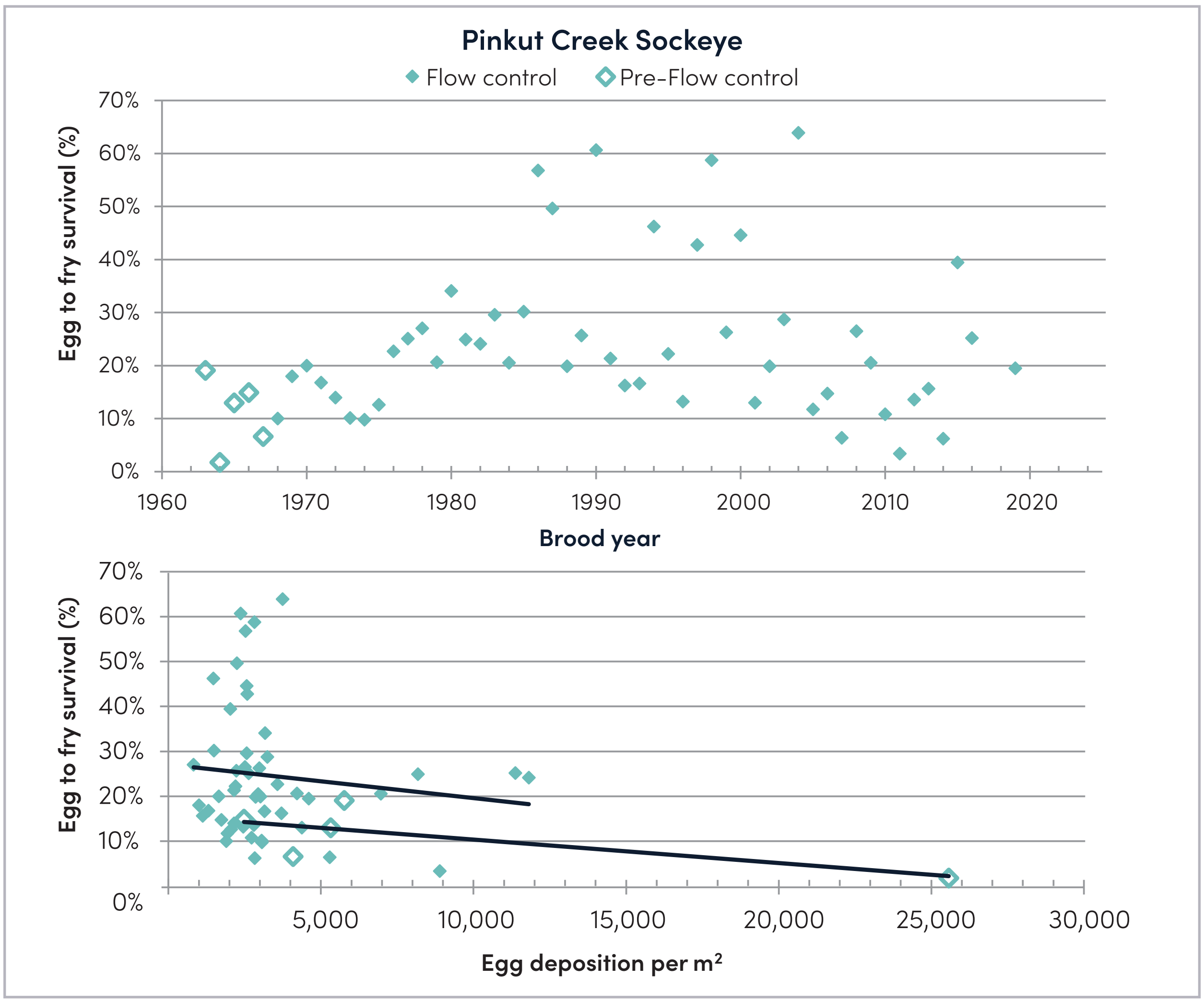



**Figure 33:** Pinkut Creek sockeye egg-to-fry survival (%), brood years 1964 to 2019 (top), and egg-to-fry survival (%) versus egg deposition per square metre (bottom). Hollow symbols indicate pre-flow control and solid symbols indicate flow control.

### Pinkut Spawning Channel

The original Pinkut Channel was built in 1968 with a river intake above the creek spawning area and a settling basin to remove silt and sand brought in from the river. Operational problems began in the first year. River water entering the channel at 0°C formed frazzle ice on the gravel surface causing scouring of the gravel and alevin mortality, and ice jams sometimes caused short circuiting of flow across the berms to adjacent legs of the channel. Siltation was also a serious problem caused by erosion of the berms from scouring by frazzle ice and spawners digging into the unarmoured sides. A warm water system was installed to pump 4°C lake water into the channel which reduced but did not entirely remove issues with frazzle ice. From 1972 to 1975, egg survival averaged only 24 percent and the spawning channel was closed in 1976 for a complete rebuild with armoured berms and expanded settling basins. Egg-to-fry survival and fry production from the first Pinkut channel are indicated in Figure 34 by hollow markers.

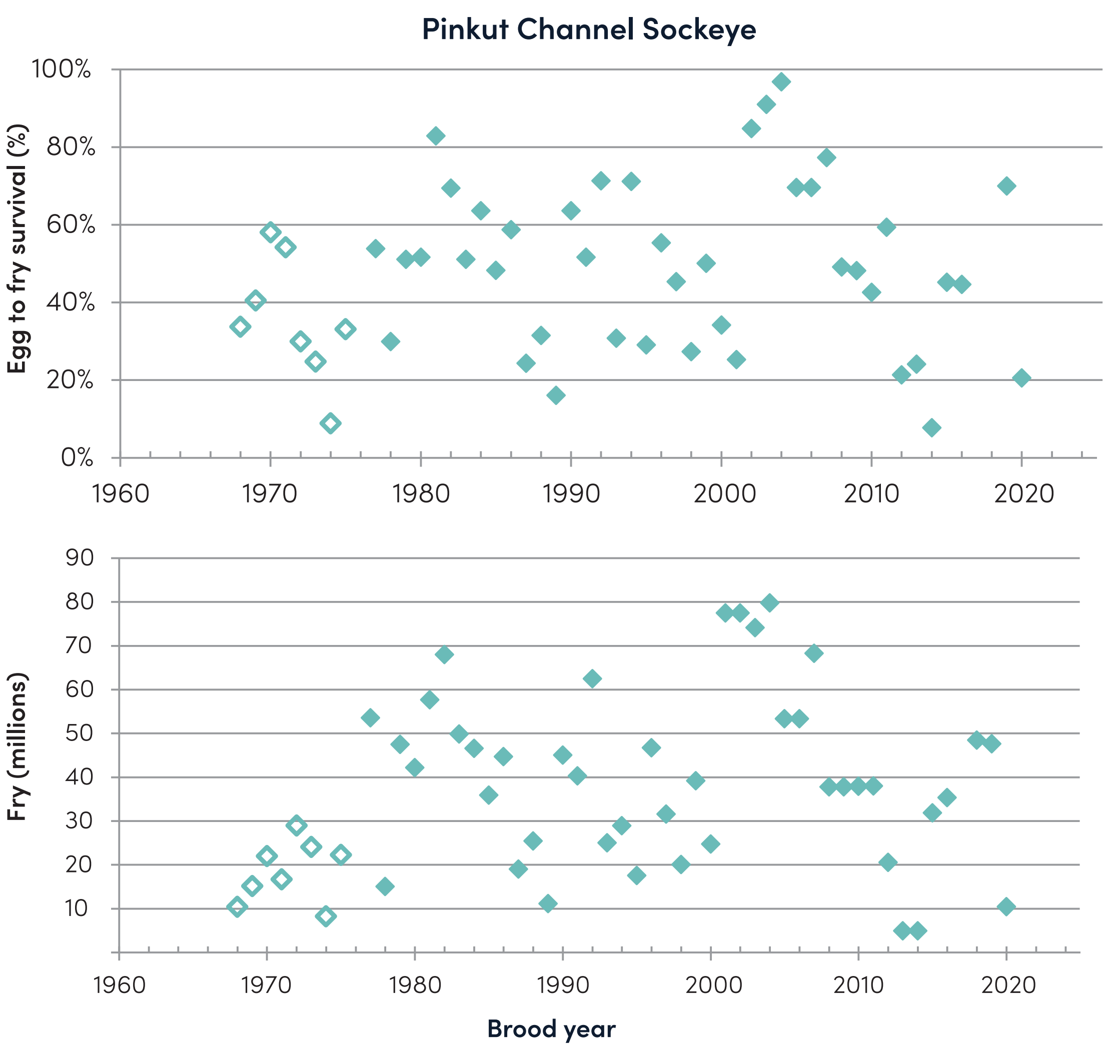



**Figure 34:** Pinkut channel sockeye egg-to-fry survival (%) (top); and fry production (millions) per square metre (bottom), brood years 1968 to 2020. Hollow markers indicate the first Pinkut Channel.

The rebuilt Pinkut channel began operations in 1977 with an immediate increase in egg survival and fry production. Spawning gravel has been cleaned with the improved air-water jet technology since 1977, and in 2017 the gravel was removed, cleaned, augmented and replaced.

*Pinkut Spawning Channel*
*Babine Lake, British Columbia.*
*Photo credit: Doug Lofthouse*

Since 1987, egg-to-fry survival and fry production in the second Pinkut channel have varied widely but averaged 52 percent and over 1,100 fry per square metre with no evidence of decreased survival or leveling off of fry production at higher observed egg densities (Fig. 35). Low fry production in 2013 was partially due to poor escapement and low egg deposition.

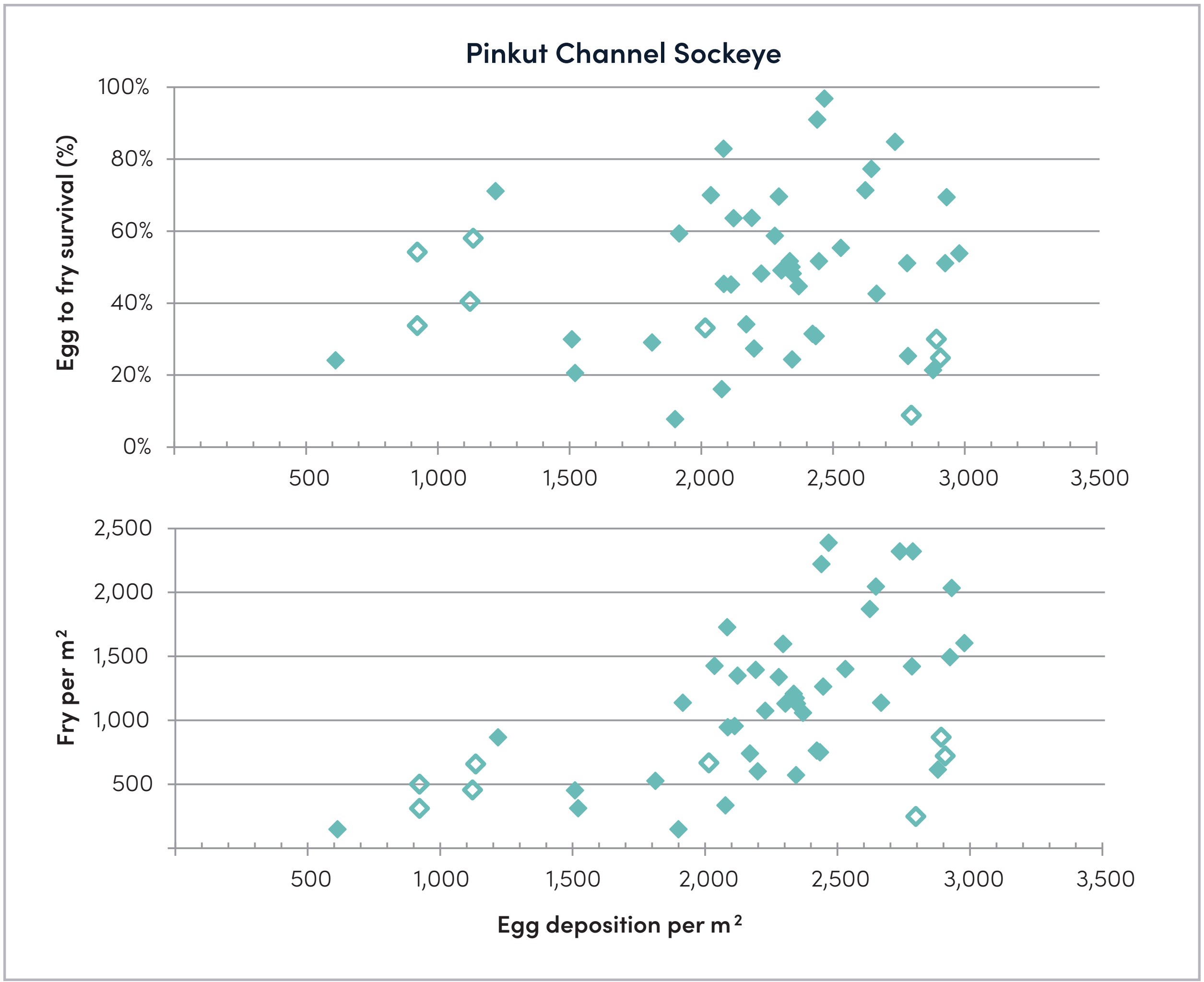



**Figure 35:** Pinkut channel sockeye egg-to-fry survival (%) (top); and fry production (millions) per square metre versus egg deposition per square metre (bottom), brood years 1968 to 2020. Hollow markers indicate the first Pinkut Channel.

The first recorded outbreak of IHN in Pinkut channel occurred in 2021. Egg-to-fry survival was low at 20.6 percent but Garver et al. (2022) noted that, based on the fry holding studies during the Weaver channel outbreak in 1987, additional IHN related mortality might have occurred after migration from the channel. The cause of the outbreak is unknown. Garver et al. (2022) noted that it was unclear if less thorough gravel cleaning in 2020 and a higher abundance of algal mats in 2021 had been contributing factors.

Pre-spawn mortality in Pinkut channel historically ranged from one to 7 percent, averaging less than four percent. Since the late 2000s, elevated PSM has become more common with a high of 22 percent in 2013. Similar to Fulton channel 2, Figure 36 shows a reduction in egg-to-fry survival and fry production at very high PSM. High water temperatures are believed to contribute to stress and increased PSM caused by Ich/Loma parasites. High temperature years have become more frequent in the past two decades necessitating the operation of the lake water pumps to cool the channel water and reduce stress on spawners, and channel operators have often been able to reload sections of the channel affected by high PSM with additional spawners to maintain fry production.

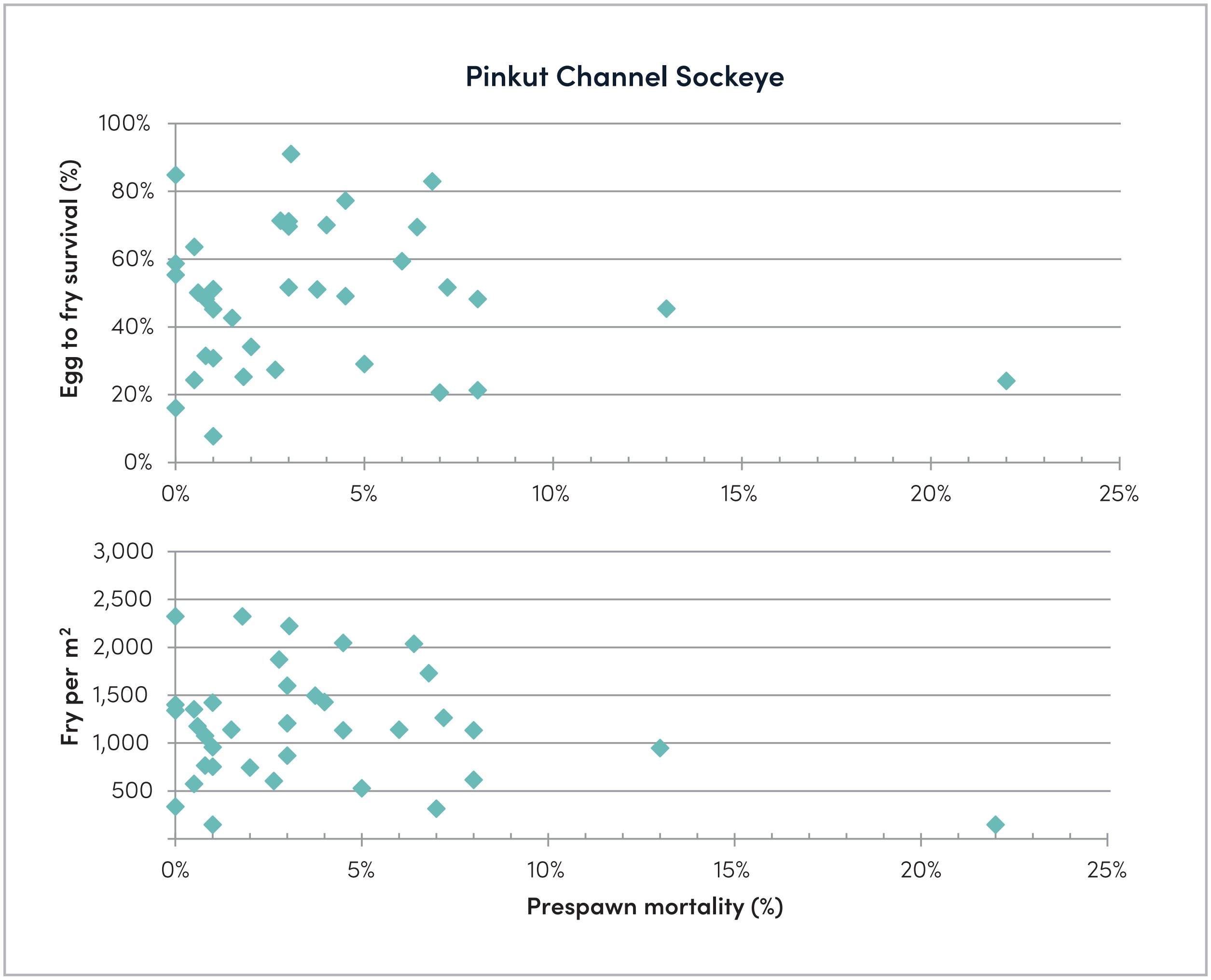



**Figure 36:** Pinkut channel sockeye egg-to-fry survival (%) (top); and fry production per square metre versus prespawn mortality (%) (bottom), brood years 1979 to 2020.

## BABINE LAKE SMOLT PRODUCTION

The Babine Lake system is unique in having a long standing smolt enumeration program located at the outlet of Nilkitkwa Lake to monitor outmigration of BLDP and wild Babine sockeye smolts. BLDP origin fry are known to rear in the main basin of Babine Lake mixed with fry from the non-enhanced main basin streams and migrate as late run smolts, separate from Babine River origin fry which rear in Nilkitkwa Lake and the north arm of Babine Lake and migrate as early run smolts.

Fin clipping in 1965-67 and 1970-71 found no substantial differences in growth, distribution or in-lake survival between channel and wild origin fry, and increased fry production was followed by corresponding increases in smolts (McDonald and Hume 1984).

Wood et al. (1998) using parsimonious models to revise fry and smolt abundance estimates, concluded fry recruitment in the main basin was still below levels required to yield maximum smolt biomass and maximum adult returns. Hume and MacLellan (2000) found the size and growth of juvenile sockeye in the main basin to be similar to that of pre-BLDP years, concluding that Babine Lake had not reached or exceeded its rearing capacity for juvenile salmon.

To estimate total main basin fry production, McDonald and Hume (1984) and Wood et al. (1998) assumed 233 fry were produced by each adult spawner in non-enhanced streams, to which the annual BLDP fry production estimates were added. For this report, main basin smolt and fry data were updated to brood year 2019 with Wood's models. Fulton and Pinkut fry which previously accounted for 50-60 percent of main basin fry have increased to 90 percent or more in recent years.

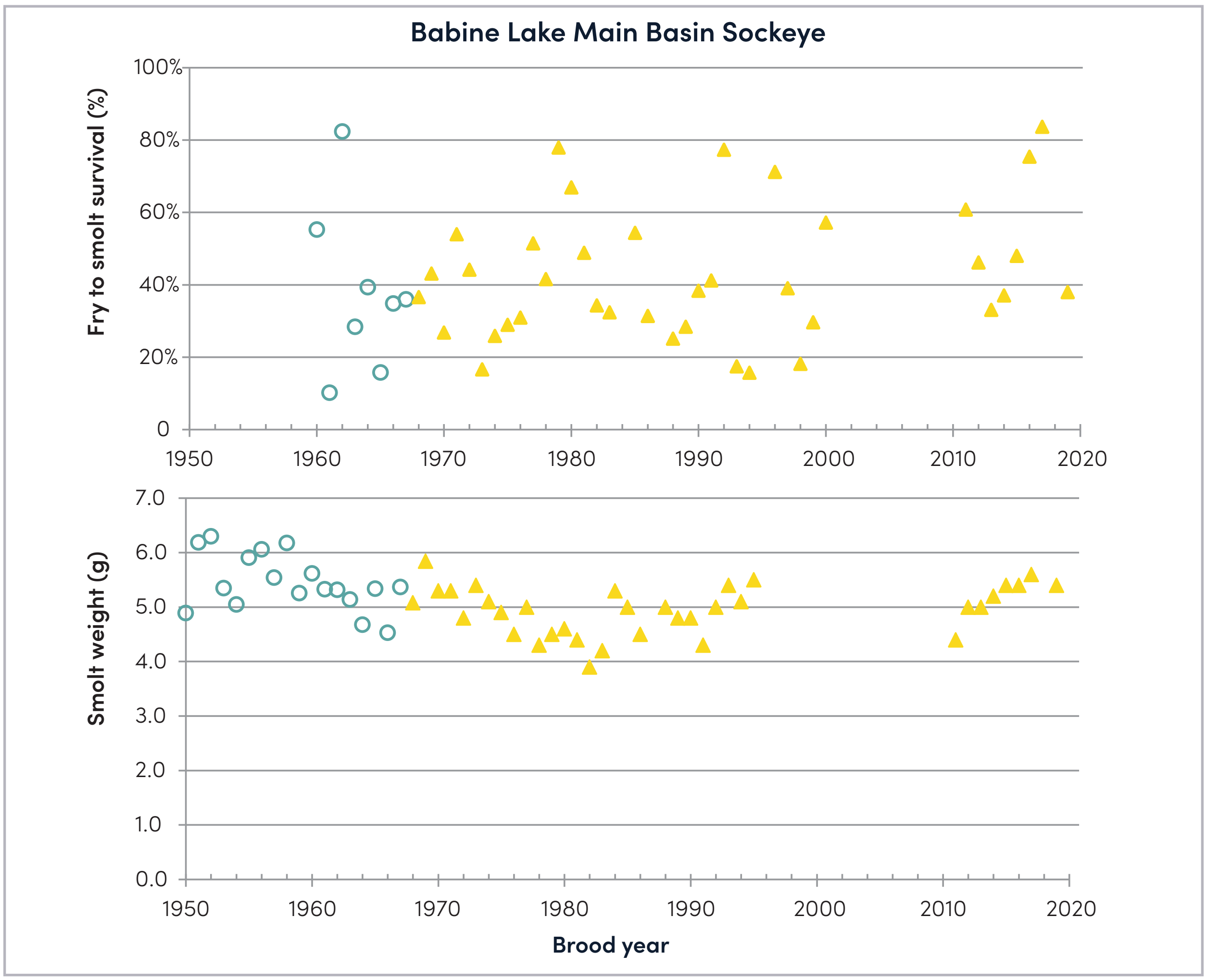



**Figure 37:** Babine Lake main basin sockeye fry-to-smolt survival (%) (top); for brood years 1960 to 2019, and smolt weight (g) for brood years 1950 to 2019. Smolts were not enumerated in some years. Pre-BLDP markers are hollow teal circles, BLDP era markers are solid yellow triangles.

Estimates of smolt abundance prior to 1960 were not included as Wood (1998) considered them less reliable because tagging methods were still being developed and abundance estimates were based on an earlier model. Fry-to-smolt survival and smolt weight have not significantly changed from pre-BLDP to brood year 2019, averaging 43.2 percent and 5.1 grams respectively (Fig. 37 previous page). Fry-to-smolt survival was not significantly affected ($p>0.50$) by fry input to the main basin but a negative density effect was found between smolt weight and fry production ($p<0.05$) (Fig. 38).

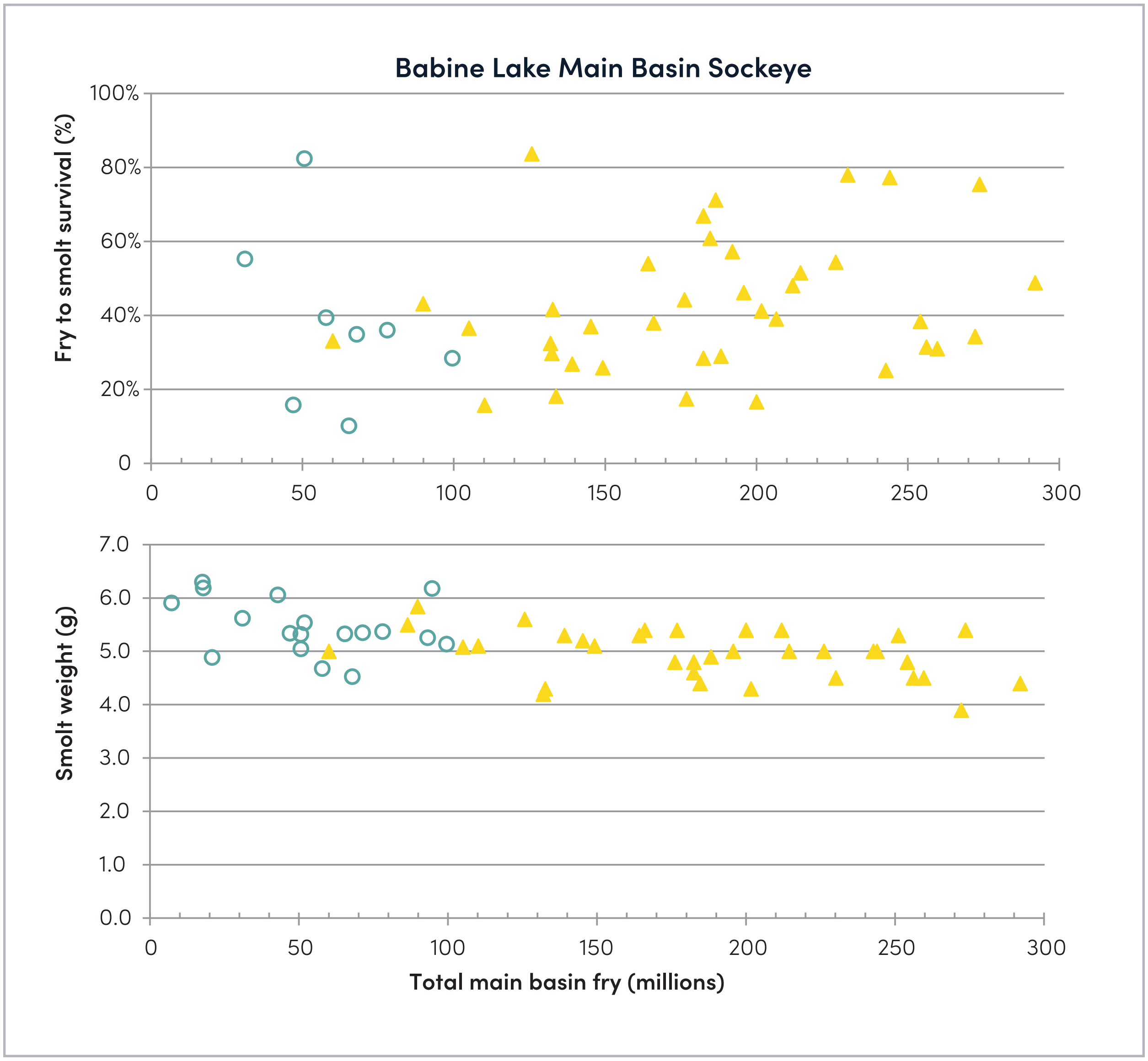



**Figure 38:** Babine Lake main basin sockeye fry-to-smolt survival (%) versus total main basin fry (millions) for brood years 1960 to 2019 (top); and smolt weight (g) versus total main basin fry (millions) (bottom). Smolts were not enumerated in some years. Pre-BLDP markers are hollow teal circles, BLDP era markers are solid yellow triangles.

## ADULT PRODUCTION FROM THE BABINE LAKE DEVELOPMENT PROJECT

BLDP sockeye are the major component of the Babine Lake sockeye, which together with the non-Babine stocks, make up the Skeena sockeye aggregate (i.e., total return to Skeena). BLDP sockeye are harvested in mixed stock Alaskan and Canadian marine fisheries, First Nation fisheries along the Skeena and Babine Rivers and in Babine Lake. Since 1993, in most years of BLDP surplus, terminal commercial ESSR fisheries have been held in Babine Lake to selectively harvest the surplus Fulton and Pinkut adults. A small recreational fishery has also been held in Babine Lake.

In 1955, Milne described the decline in the Skeena commercial sockeye fishery from a high of around 2,250,000 fishes in 1910 to lows around 335,000 sockeye in 1933 and 1943, recommending that improved accuracy of catch and effort statistics, and detailed information on escapement and marine and freshwater survival were required to establish a sound system of regulation. Brett (1952) described the escapement monitoring program begun in 1944 by the Fisheries Research Board of Canada, Pacific Biological Station, noting that Babine Lake averaged 70.8 percent of the Skeena escapement in 1946 and 1947.

The Babine River slide in 1951 affected two years of escapement to the Babine system. Escapements to non-Babine stocks also declined during this period. Larkin and McDonald (1968) reported a rebuilding of Babine sockeye stocks from a 1946-48 average escapement of approximately 430,000 to an average of over 600,000 by 1959-63. However, non-Babine stocks declined from approximately 180,000 to 50,000 pieces. Larkin and McDonald noted that non-Babine stocks were less productive than Babine stocks.

A result of the long decline of the Skeena fishery and the effects of the Babine slide was the creation of the Skeena Salmon Management Committee in 1954 and eventually the construction of the BLDP in the mid-1960s, completed in 1971.

Methods to estimate adult sockeye production from the BLDP have evolved over time. Initial attempts to assess adult returns using fin clips were not successful due to fin regeneration (McDonald 1969). In the 1980s, run reconstruction based on earlier marine and in-river adult tagging studies was used to partition commercial and First Nation catches into stock groups which was combined with escapement estimates into the various Skeena and Babine Lake tributaries (West and Mason 1987). Wood et al. (1998) developed a reconstruction model with improved estimates of the distribution of the unobserved spawner component and fry production within Babine Lake, and over the past two decades DNA information has improved the identification of stock groups in the commercial fisheries.

West and Mason (1987) reported the catch of Fulton and Pinkut sockeye increased from a pre-BLDP average of 212,441 to 825,729 pieces from 1973 to 1985 (Fig. 39 next page). Total BLDP catch continued to increase, averaging 1.065 million pieces from 1982 to 1991, and 1.673 million from 1992 to 2001. However, annual catch has become more variable and has declined since the early 2000s, averaging 488,000 pieces over the past twenty years.

Photo by: Tavish Campbell

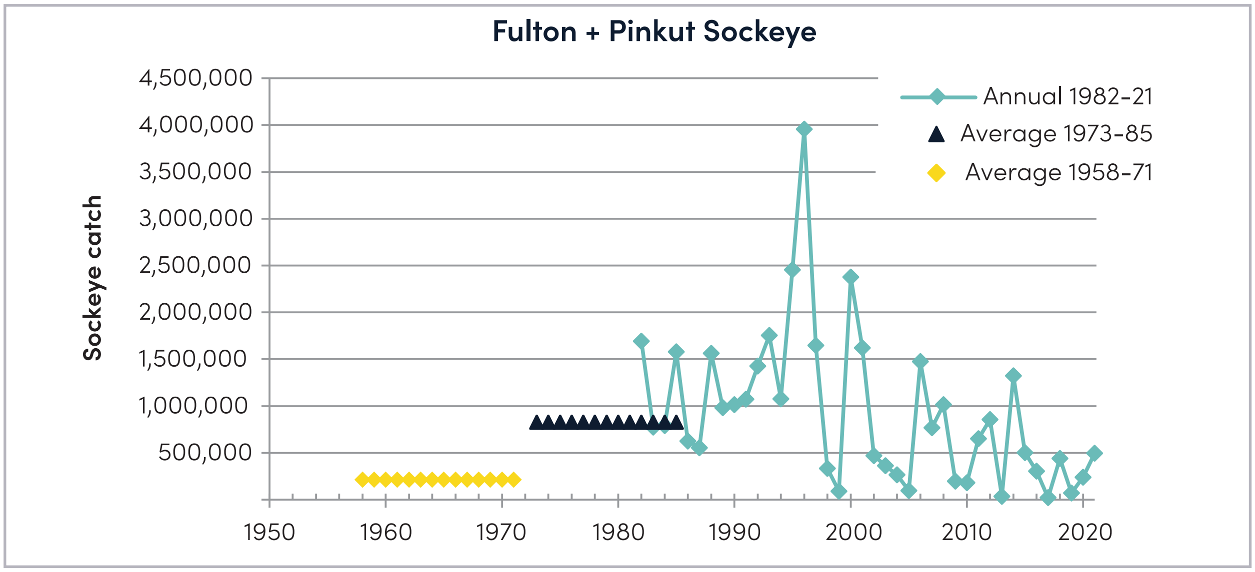



**Figure 39:** Fulton and Pinkut sockeye catch, including commercial, excess salmon to spawning requirement (ESSR), and First Nation catch. Average catches from 1958 to 1971 (pre-BLDP adult returns) and 1973 to 1985 from West and Mason (1987). Annual catch from 1982 to 2021 from DFO, Prince Rupert Stock Assessment Division.

While total catch including terminal ESSR fisheries has declined, escapement has remained above pre-BLDP levels, averaging 703,000 pieces since 2001 (Fig. 40). In some years, available surplus above the combined Fulton and Pinkut escapement target of approximately 500,000 pieces was not harvested.

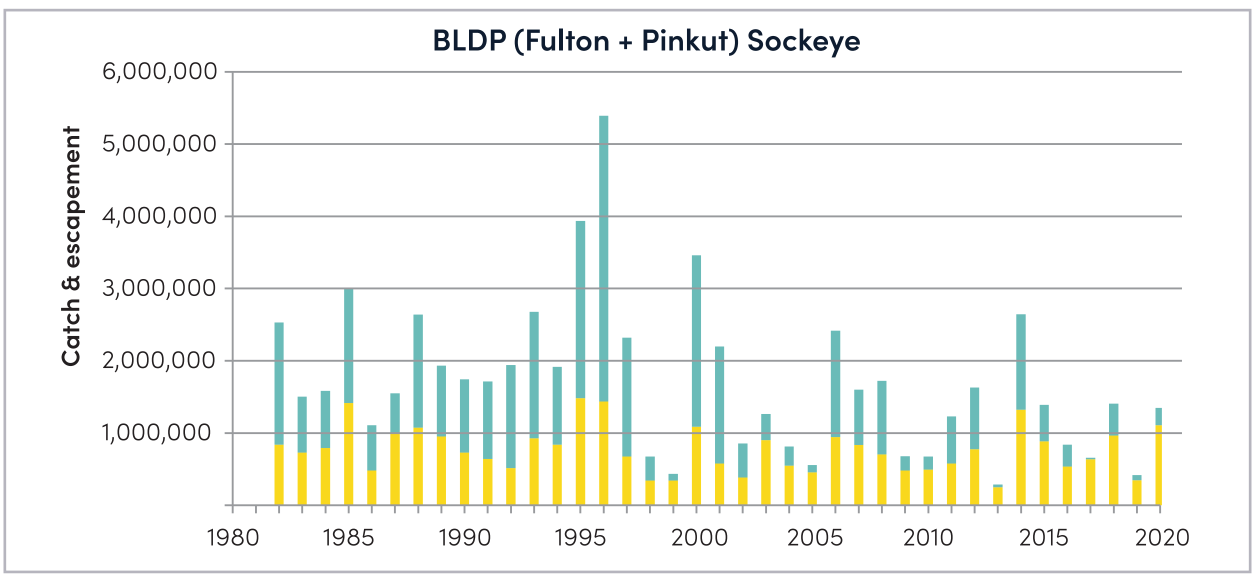



**Figure 40:** BLDP (Fulton + Pinkut) sockeye catch (teal) above escapement (yellow), return years 1982 to 2020. Catch includes commercial, ESSR and First Nation catches. Data source: NuSEDS and DFO Stock Assessment Division.

The effect of the BLDP on non-enhanced Skeena sockeye stocks has been investigated by many authors. While the freshwater rearing capacity of Babine Lake does not appear to have been exceeded, competition between enhanced and non-enhanced stocks, mixed stock fishery effects and disease have been identified as areas of concern.

Peterman (1982) and McDonald and Hume (1984) found a non-linear relationship between adult production and smolt abundance, and a lack of response to increased smolt production in even-numbered years, suggesting competition with juvenile Skeena pink salmon might affect sockeye smolt to adult survival. More than a decade later, Wood et al. (1998) found the relationship between adult returns and Babine smolt production was still non-linear, but noted the difference between even and odd years was no longer evident suggesting more favourable conditions may have relaxed the density dependence.

Conversely to common year of ocean entry, West and Mason (1987) looking for possible ocean effects found fecundity of BLDP age 42 and 52 females to be more closely related to common year of return rather than common brood year. The analysis was based on fecundity — length data from 1964 to 1985 and it is possible that their conclusion would no longer hold given today's ocean environment.

Adult escapement to the non-enhanced Babine stocks was found by Wood et al. (1998) to be not significantly different from pre-BLDP levels, except for the Morrison Arm stock with similar run timing to Fulton and Pinkut.

In 2001, Wood noted that while escapement to Babine had increased, escapements of non-Babine stocks had declined by an order of magnitude from 1950 to 1976, almost regained historic (1950) levels by 1995 and then declined alarmingly since 1996. Recovery of the non-Babine stocks had been attributed to reduced exploitation and selective harvest of BLDP fish (in Canadian fisheries), but Wood offered an alternative explanation of recovery due to increased marine survival that peaked in 1990 and 1991 and did not continue to increase while non-Babine stocks had undergone chronic over-exploitation. Wood also noted increasing harvests of Skeena sockeye in Alaskan fisheries.

Following a controversial fishing season in 2006 when a large sockeye return coincided with a relatively weak steelhead return which was impacted by an extended commercial fishery opening, an Independent Science Review Panel was convened to review the current management practices. The Panel's objectives were to recommend a new approach to management and to identify additional monitoring and data collection to implement the Wild Salmon Policy. Recommendations of the Panel (Walters, et al. 2008) included, in addition to improved monitoring of escapement and productivity of wild stocks, a recommendation to examine the full costs and benefits of continued or reduced operation of the BLDP, noting the channels had exacerbated mixed-stock fishery problems and potentially reduced survival of wild stocks.

Cox-Rogers and Spilsted (2012) updated the assessment of Babine stocks and found that Babine had increased to 90 percent of all Skeena River sockeye, with 75 percent of the Babine fish being of BLDP origin. They also found a declining trend in the late-run Babine River sockeye which had not been evident in the mid-1990s assessment.

Price and Connors (2014) carried out a detailed review of the relationships between the productivity of wild Skeena sockeye and the abundance of BLDP origin smolts. They did not find support for the hypothesis that the productivity of wild Skeena sockeye was inversely related to the abundance of BLDP smolts, however, they noted their analysis may not have had power to detect smaller effects because of large variability in mortality processes that could obscure an effect, or have been affected by poor data quality. They did find limited support for the hypothesis that productivity of Skeena sockeye Conservation Units (CUs) was negatively related to Sea Surface Temperature (SST) in the months preceding marine entry.

# BIG QUALICUM RIVER DEVELOPMENT PROJECT

The Big Qualicum River Salmon Development Project, designed in the early 1960s, was intended to increase freshwater survival and production of chum, Chinook, coho and steelhead. Studies by Wickett (1952) had predicted that a fishery of 1,700,000 salmon could be supported by flow control and stream-bed improvements. Chum were expected to receive the largest benefit because some 95 percent of pre-adult mortality occurred in the freshwater stage.

The project initially consisted of river flow control works at the outlet of Horne Lake, a flood diversion channel on Hunt's Creek, improvements to the river spawning areas, an experimental artificial spawning channel that was later replaced with a larger channel with improved design characteristics, and a river counting fence located below the spawning channels and major river spawning areas. A description of the project and its early results are provided by Fraser et al. (1983). Over time, additional hatchery facilities were built. The project has also provided much information for the design of subsequent enhancement projects at other sites.

## BIG QUALICUM RIVER FLOW CONTROL

In 1963, flow control was completed on the Big Qualicum River with construction of the Horne Lake dam and regulating works.

Only 20 percent of the wetted area of Big Qualicum River was thought to be suitable spawning area with much of the river suffering from steep slope, gravel compaction and log jams (Fraser et al. 1983). To meet the overall target of accommodating 150,000 chum spawners in the Big Qualicum system, at 1.5 square metres per female and 50 percent sex ratio, and additional 65,000 square metres of river spawning area was required.

Stream improvement operations were carried out from 1964 to 1969, consisting of widening of the river, creation of side channels, removal of log jams, installation of weirs, grading of slope and gravel addition. Ongoing maintenance has included repair of weirs, opening paths through log jams, excavating holding pools and gravel cleaning.

Photo by: Tavish Campbell

Fraser et al. (1983) reported chum egg-to-fry survival more than doubled from 13.7 percent in the pre-flow control period of 1959-62 to 29.1 percent for the 1963-72 broods. In addition to flow control coming into effect in 1963, river spawning areas were upgraded between 1964 and 1969 by gravel addition, grading and widening of spawning areas, creation of side channels and log jam removal. Since that time, cleaning of the river gravel has also been conducted in many years. Pre-flow control brood years are indicated by hollow markers in Figure 41.

Egg-to-fry survival and fry production from the river remained high through the 2000s. However, since 2008, egg-to-fry survivals in the ten to 20 percent range, typical of the pre-development period, have occurred frequently. Low fry production in brood years 2008-2010, 2014 and 2018 was caused by low spawning escapements and egg deposition.

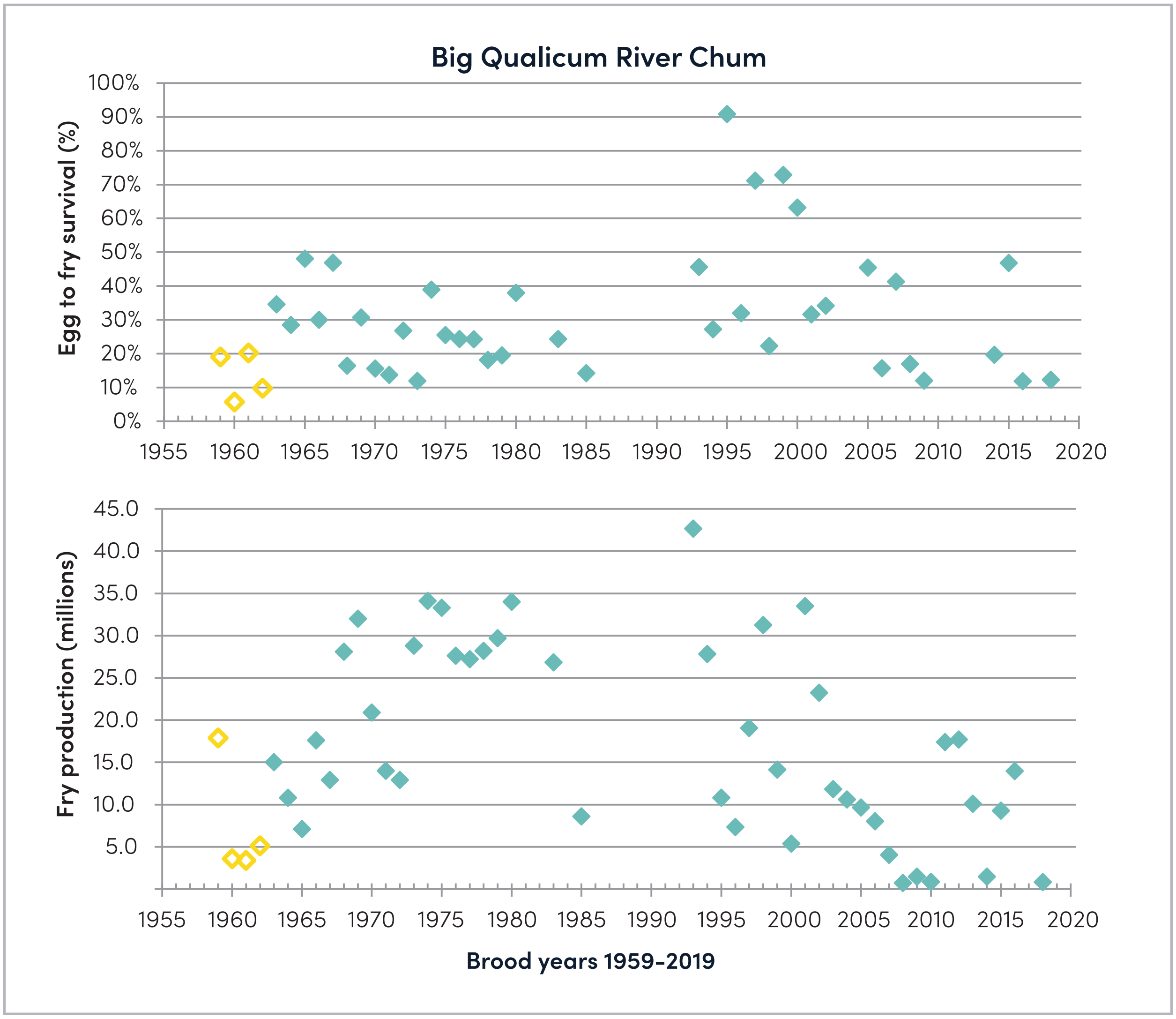



**Figure 41:** Big Qualicum River chum salmon egg-to-fry survival (%) (top); and fry production (millions) (bottom), brood years 1959 to 2019. Pre-flow control years indicated by yellow hollow markers.

## BIG QUALICUM SPAWNING CHANNEL 1

Big Qualicum spawning channel 1 was completed in 1963, with a river intake and discharge back to the river at the main enumeration fence. The channel operated from 1963 to 1969, primarily for chum salmon and with up to 100 coho spawners annually, 70 Chinook spawners recorded in 1964, and eyed pink salmon eggs planted in 1963 and 1964. Chum egg-to-fry survival and fry production averaged 36 percent and 0.9 million fry respectively (Fig. 42). Fraser et al. (1983) noted that channel 1 was relatively small and over its operational life accounted for approximately three percent of the chum eggs in the Big Qualicum system. In 1969, channel 1 was converted to a rearing channel.


**Figure 42:** Big Qualicum chum salmon spawning channels 1 and 2, egg-to-fry survival (%) (top); and fry production (millions) (bottom), brood years 1963 to 2020. Channel 1 and 2 indicated by yellow hollow and solid teal markers respectively.

## BIG QUALICUM SPAWNING CHANNEL 2

Big Qualicum channel 2 was completed in 1967, upstream of channel 1 and the main river fence. Based on experience from channel 1, channel 2 included a settling basin and steeper slope. Adults are enumerated through a fence at the channel exit and spawner distribution is controlled within the channel by closing partition fences when target spawner densities are reached. Live sampling at the main river fence for fecundity with age and length, and dead sampling of channel spawners for age, sex, length and egg retention is used to estimate egg deposition.

Egg-to-fry survival and fry production in channel 2 have averaged 59 percent and 13.3 million respectively (Fig. 42). Data for all but two years: from 1981 to 1992, were not available for this analysis. Since 1993, egg-to-fry survival has decreased slightly but is still high, averaging 54 percent. Low fry output in 1996, 2000, 2018 and 2019 was due to low spawning escapements and egg deposition.

The combined 1967-2020 brood years do not show a significant density dependence between egg-to-fry survival and egg deposition per square metre ($p>0.50$) but the earlier 1967-1985 brood years which had a larger proportion of higher egg depositions did have a significant ($p<0.05$) negative relationship (Fig 43.). Fry production per square metre appears to reach a maximum at egg depositions over 2,500 eggs per square metre. Also, egg-to-fry survival and fry production in the 1993 to 2020 period appear to be lower than those of the earlier 1967 to 1985 period at corresponding egg depositions. No explanation is offered but investigation could examine possible changes in environmental or channel conditions, spawner or gamete viability or assessment methods.


**Figure 43:** Big Qualicum chum spawning channel 2, egg-to-fry survival (%) (top); and fry production per square metre versus egg deposition per square metre (bottom). Brood years 1967 to 1985 and brood years 1993 to 2020 are indicated by hollow and solid markers respectively.

## ADULT PRODUCTION FROM THE BIG QUALICUM RIVER DEVELOPMENT PROJECT

Big Qualicum chum are primarily harvested in mixed stock fisheries in Johnstone Strait (Statistical Areas 12 and 13) and terminally in Statistical Area 14.

Prior to 1983, the management approach in Johnstone Strait was to harvest surpluses in excess of a combined escapement goal for all stocks. To improve protection and rebuilding of wild stocks, a Clockwork management strategy was implemented in 1983 (Hilborn and Luedke 1987) with variable harvest rates dependent on run size to manage chum harvests in Johnstone Strait (PSC 1987, Ryall et al. 1999). Harvest rate thresholds were reviewed and updated in 1986 and again in 1991, resulting in the total estimated wild escapement goal being met or exceeded in four out of eight years from 1994 through 2001 which was considered a significant improvement over the previous eight years when the wild escapement goal was not met in any year. After further reviews and consultation, the Clockwork strategy was replaced in 2002 with a stable fishing schedule approximating a fixed exploitation rate less than 20 percent (PSC 1987).

The terminal chum fishery in Qualicum Bay (Statistical Area 14) targets enhanced Big Qualicum, Little Qualicum and Puntledge River chum stocks. Management of this fishery also considers conservation requirements of passing wild and enhanced chum stocks, Chinook, and coho (PSC 2003).

In the early years of the Big Qualicum Development Project, a fin clipping program with recovery of marks in commercial fisheries and escapement was carried out to compare marine survival of channel and river origin fry. Fraser et al. (1983) found survival of the two groups to be comparable, noting that channel 1 fry survived at an average of 1.21 percent compared to 1.02 percent for river fry but within group variance made the difference insignificant (Fig. 44).

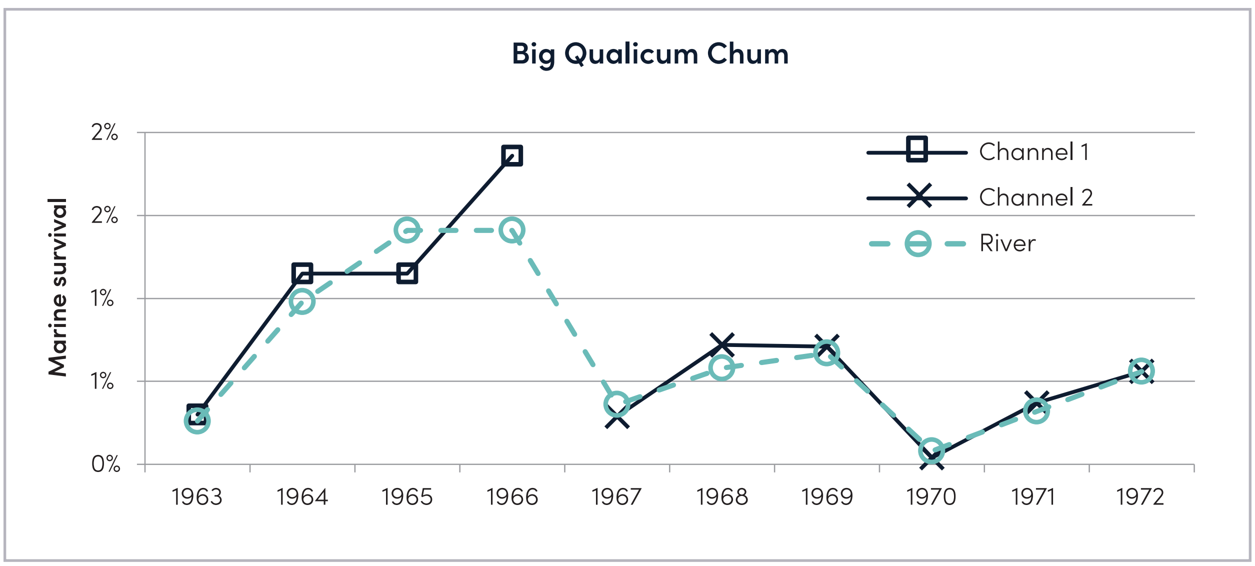



**Figure 44:** Marine survival of chum salmon from Big Qualicum spawning channel 1 (dark blue with hollow squares), spawning channel 2 (dark blue with x) and Big Qualicum River (dashed teal with open circle), brood years 1963 to 2012 (data from Fraser (1983).

Commercial catch of BQ chum is estimated by mark recovery of fin clips. After a hiatus of eight years, fin clipping of Big Qualicum chum was resumed in 1981. River and channel fry were no longer marked differentially, and Big Qualicum chum are now the indicator stock for SEP enhanced unfed chum stocks. Commercial catch reported for 1962 to 1975 by Fraser et al. (1983) and for 1980 to 2016 by Lynch et al. (2020) is shown in Figure 45. Catch information was not available from 1976 to 1979 and there was no southern chum fishery on the Big Qualicum stock in 2015.

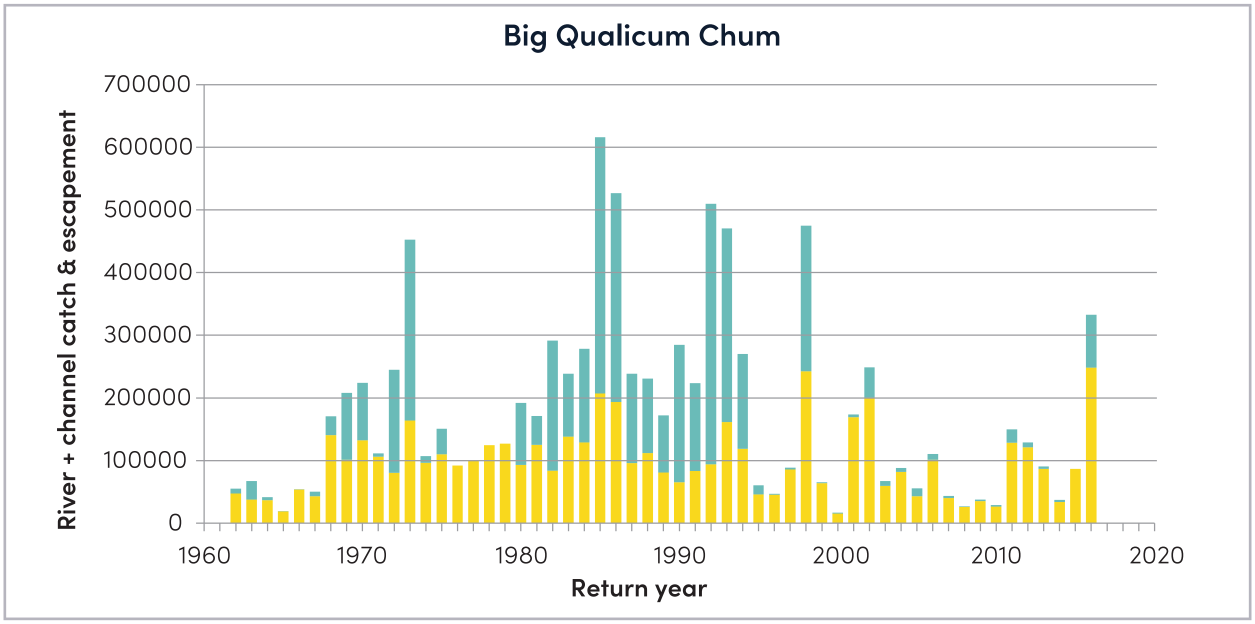



**Figure 45:** Big Qualicum chum (river + channel) catch (teal) above escapement (yellow). Catch data 1962-1975 from Fraser et al. (1983), catch data 1980 to 2016 from Lynch et al. (2020) and escapement data 1953 to 2021 from DFO NuSEDS.

Information on pre-development commercial chum catch is limited. Fraser et al. (1983) commented that an optimistic estimate of chum catches in the 12 years prior to 1959 was 100,000, but the catch estimates they provided for 1962 to 1965 prior to enhanced returns averaged only 10,658 chum.

From 1968, after escapement rebuilt, to 1994, commercial catch averaged 160,000 pieces. Since 1994, there have been many years of low escapement with small BQ catches harvested mostly in the Johnstone Strait mixed stock fishery, and some years of substantial returns when surplus was not harvested terminally in the Area 14 fishery, likely due to conservation concerns for other stocks, and escapement exceeded the 85,000 chum target.

The very low chum escapements in recent years are not explained but similar downturns have also occurred in the nearby Little Qualicum and Puntledge Rivers and other east coast Vancouver Island chum stocks. Poor chum salmon returns were widespread in recent years.

## LITTLE QUALICUM SPAWNING CHANNEL

The Little Qualicum River spawning channel was built in 1979 to enhance the local chum population. The channel has a river intake, settling basin and capacity for approximately 50,000 spawners.

Egg-to-fry survival was initially very high, around 90 percent but declined sharply from 1979 to 1985 due to accumulating silt. The settling basin was found to remove most sand and to reduce suspended solids by approximately 50 percent but much of the remaining lighter silt and clay were found to settle in the spawning gravel (Sweeten et al. 2003). Beginning in 1986, gravel cleaning has been carried out in most years by scarification with a D7 bulldozer and pumping the effluent to a large grassy field which acts as a filter to remove sediment before the flow returns to the river (McLean 2000). A detailed manual for gravel cleaning in the Little Qualicum spawning channel was developed by Sweeten (2005).

Since gravel cleaning began in 1986, egg-to-fry survival has averaged 60 percent with no declining trend. Low fry production in some years is the result of low spawning escapements and egg deposition in the channel (Fig. 46).

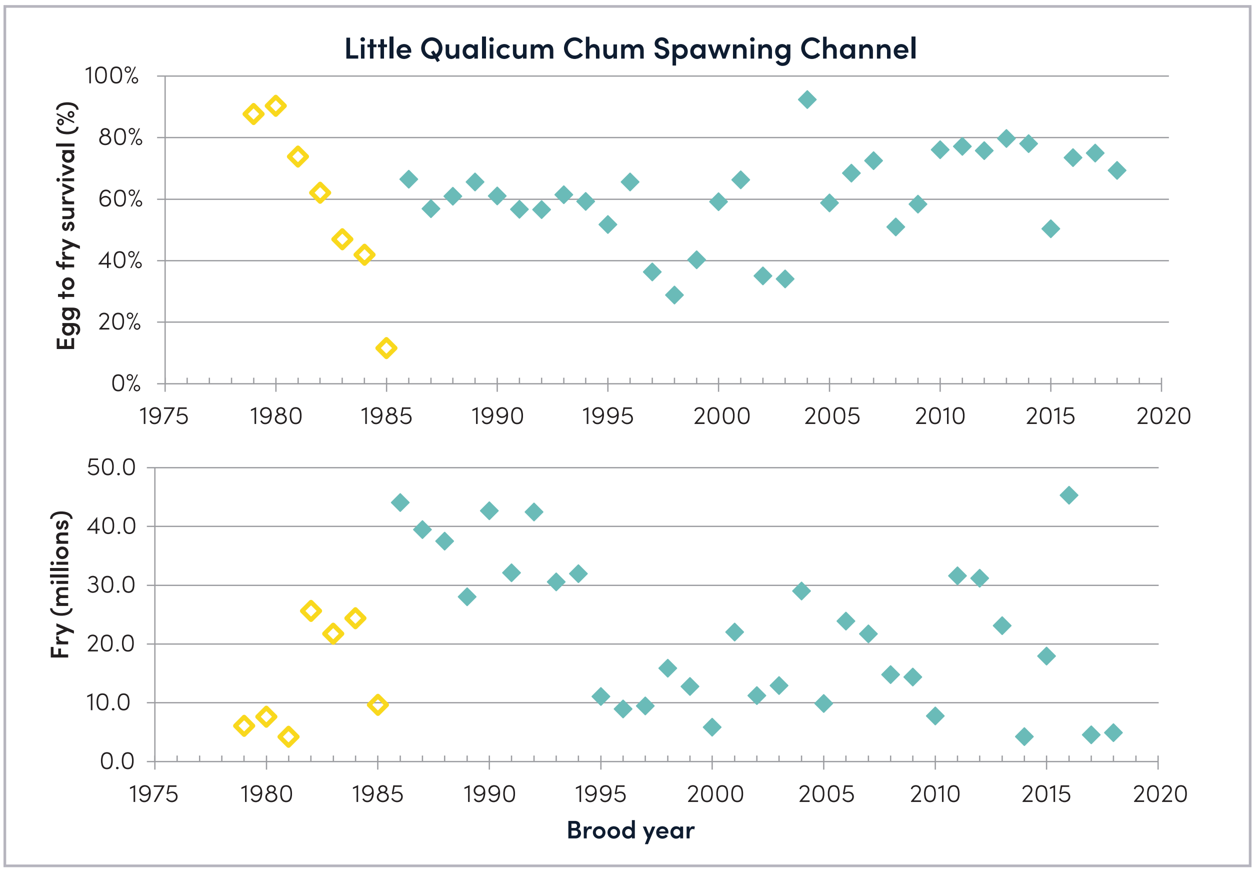



**Figure 46:** Little Qualicum chum spawning channel egg-to-fry survival (%) (top); and fry production (millions) (bottom), brood years 1979 to 2018. Pre-gravel cleaning years indicated by yellow hollow markers.

Egg-to-fry survival and fry production do not show a negative relationship over the observed range of egg deposition, indicating the Little Qualicum spawning channel has not exceeded its target spawning density (Fig. 47). In recent years, the channel has not been cleaned on an annual basis.

The Little Qualicum spawning channel has been operated passively in the past few years with open access for spawners, and spawner enumeration is now provided by DFO's Stock Assessment Division.

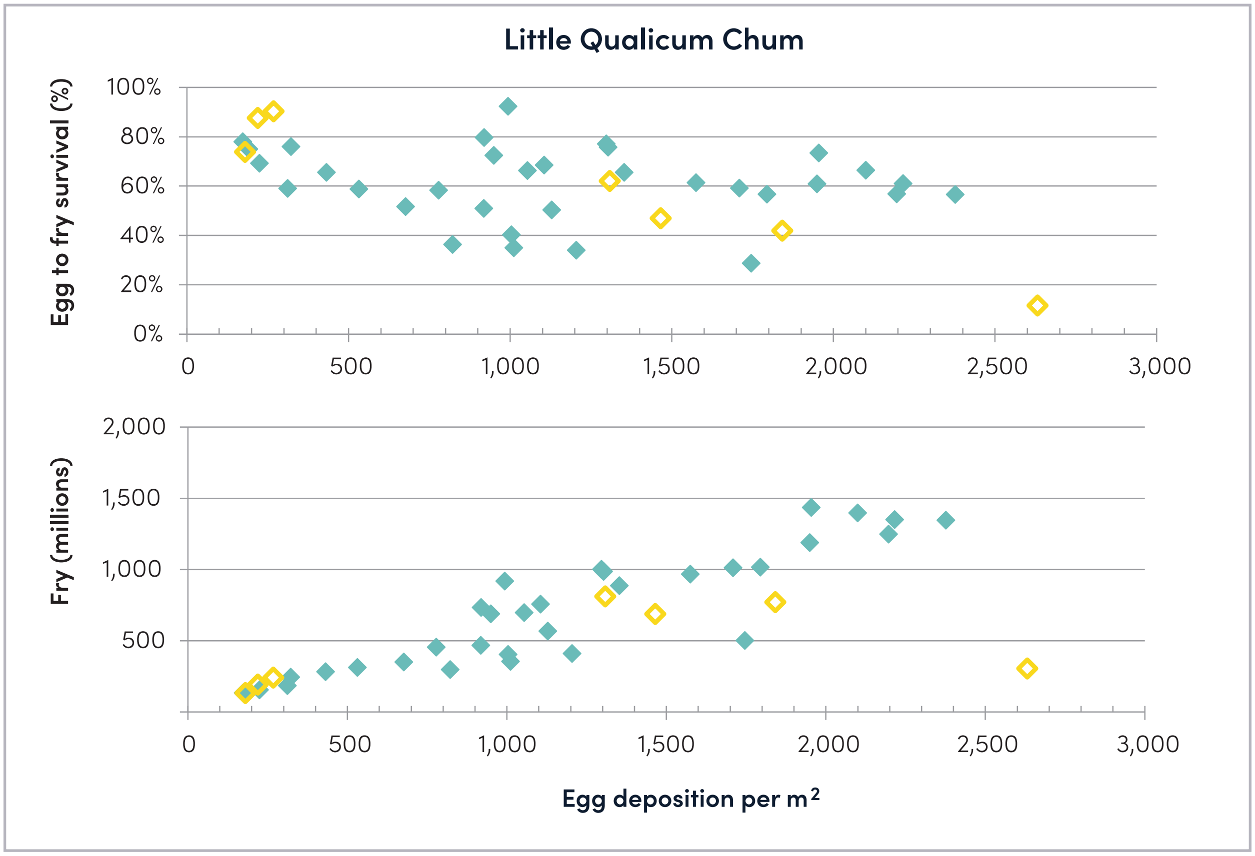



**Figure 47:** Little Qualicum chum spawning channel egg-to-fry survival (%) (top); and fry production (millions), versus egg deposition per square metre (bottom), brood years 1979 to 2018. Pre-gravel cleaning years indicated by yellow hollow markers.

## ATNARKO RIVER SPAWNING CHANNEL

The Atnarko channel was built in 1986 to enhance pink salmon in the Bella Coola River system. Limited information on the channel was available for this review. The channel had a design capacity of approximately 70,000 spawners but pink salmon were only moderately attracted into the channel and loading the channel was made more difficult by numerous grizzly bears at the channel site. Spawners were estimated visually and over the channel's 11 years of operation its spawning escapement ranged from 1,100 to 20,000 adults, averaging just over 10,000. Fry production was not estimated.

The channel had a river intake which deposited silt in the channel. Concern over silt from gravel cleaning moving back into the river restricted gravel cleaning and after the 1996 brood, the site was no longer operated as a spawning channel. The upper end of the site was developed into Chinook rearing ponds and the juveniles are released through the channel (Haakon Hammer pers. comm.). Very shortly after the spawning channel began operating, its cobble sides were found to provide substantial natural rearing habitat for salmonids. In the early 1990s the channel was complexed with large woody debris, boulders and riparian cover to enhance salmonid rearing capacity.

## HORSEFLY RIVER SPAWNING CHANNEL

The Horsefly River spawning channel was build in 1989 to enhance subdominant and off-cycle years of the Horsefly sockeye run, and has not been operated in many of the dominant Horsefly return years.

The channel has a river intake and settling basin but the gravel has been prone to heavy siltation causing low egg-to-fry survival in some years (Fig. 48). Survival in the first four years was initially very high, ranging from 64 to 79 percent until declining significantly in the next four brood years. Gravel cleaning with a 'Babine rake', a frame with one foot long steel spikes bolted to the underside of a bulldozer bucket and combed through the gravel with water flowing to carry silt away, was tried in 1995 and 1996 but was not effective. The spawning gravel was removed and replaced in 1997 and 2001 and egg-to-fry survival returned to high levels in the 75 to 87 percent range. Subsequent gravel cleaning in some years using the Babine rake or an excavator to rake and dump the gravel have had some success but are not as effective as the more costly and thorough method of removing and replacing the gravel.

A temporary partial weir in the river diverts spawners into the channel. In 2014, the channel exit was modified to improve attraction, but escapements to the river and into the channel have been low in most years. Escapement estimates are now provided by the DFO Stock Assessment Division. The last brood year for which a fry enumeration program was conducted was 2014. Spawner and egg densities have not been so high as to affect egg-to-fry survival (Fig. 49). Fry production has been affected by the quality of gravel cleaning and low numbers of spawners.

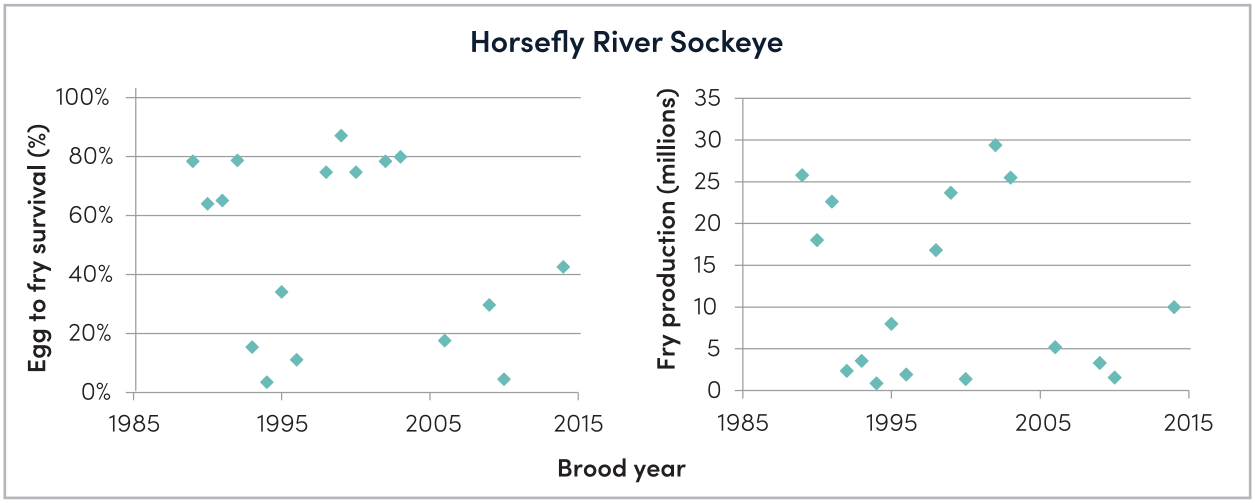



**Figure 48:** Horsefly River sockeye spawning channel egg-to-fry survival (%) (left); and fry production (millions) (right), brood years 1989 to 2014.

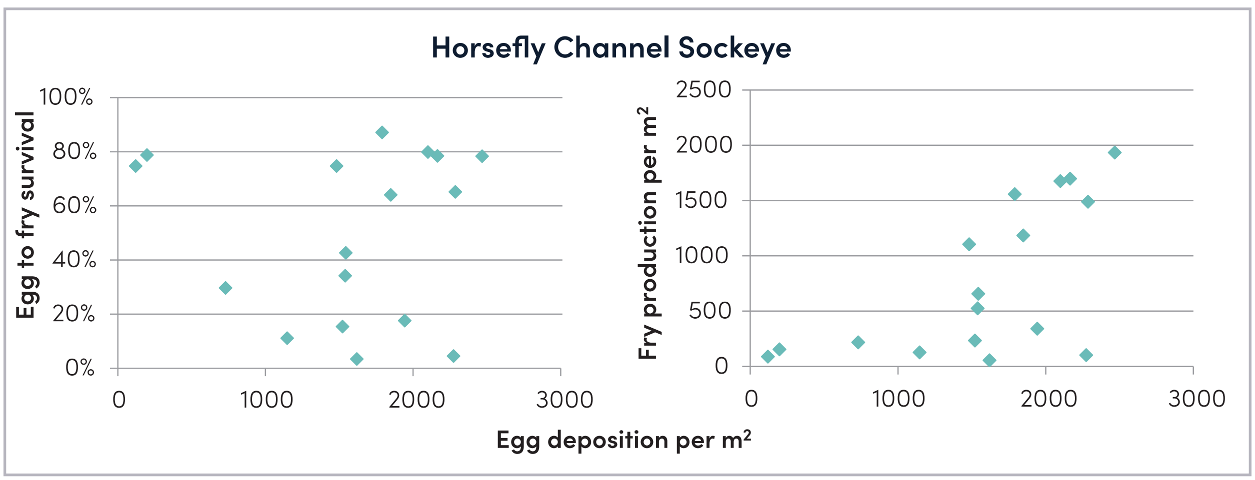



**Figure 49:** Egg-to-fry survival (%) (left) and fry production (millions) (right) from the Horsefly River sockeye spawning channel, brood years 1989 to 2014.

# UNMANNED SPAWNING CHANNELS

In the mid to late 1980s, tighter constraints on funding and manpower led to the construction of unmanned spawning channels that could be maintained by a local guardian with spot evaluation in key times by a contracted crew. Some success with this strategy had already been achieved by SEP's Special Projects Division on a smaller scale with restoration of side channels and SEP Engineering Division embarked on the construction of larger scale unmanned channels. The unmanned channels suffered a number of problems impacting their productivity (Bruce Shepherd pers. comm.).

Six unmanned spawning channels were built. Five were located on mainland coastal inlets and one in the BC Interior on the Chilko River. Information on the performance of these channels is sparse due to the lack of assessment programs that would normally be associated with major spawning channels.

## PHILLIPS RIVER SPAWNING CHANNEL

The Phillips spawning channel was constructed in 1984 for pink salmon and was the first of the unmanned spawning channels. The channel was located immediately below Phillips Lake for a relatively stable and sediment free water supply. However, it suffered a series of breaching and siltation events from nearby Wash Creek near the top end of the spawning channel.

Lawley et al. (2009) describes how in 1988/89 Wash Creek breached the separation between it and the channel, depositing large amounts of sediment. The channel was re-excavated and the breach repaired by construction of a road that acted as a protective dyke. In winter 2000/01, a second breach occurred and diverted flow from the channel into Wash Creek. A third breach in 2007 was caused by a landslide that washed away a section of the protective road and large amounts of coarse landslide material was deposited into the creek and channel. Aggradation also reduced flow in the channel and caused some flow to go subsurface. An assessment of the watershed in Nov/Dec 2007 identified restoring Wash Creek to its original channel, repair of the dyke and excavation of landslide material from the spawning channel as a priority restoration opportunity (McIntosh and Wright 2008).

NuSEDS does not identify separate spawning escapements for the spawning channel. Since 1990, odd and even year pink escapements to the Phillips River have increased by a factor of approximately three compared to the previous 55 years, but the effect of the channel cannot be determined because of the absence of assessment programs and lack of knowledge of the condition of the channel.

## NEKITE RIVER SPAWNING CHANNEL

The Nekite spawning channel was built for chum salmon in 1986, and is located 10 kilometres upstream from the mouth of the Nekite River at the head of Smith Inlet.

In 1988, 1989, and 1990, DFO North Coast staff used beach seines and diversion fences to load more adult chum salmon into the channel, speculating that returning progeny might be more attracted to the channel (Winther et al. 1989, Bachen et al. 1990, Bachen et al. 1991).

A flood in November 1989 caused heavy silting of the upper portion of the channel, but investigation by excavating with a shovel in January and February indicated good survival to eyed or hatched stages in many areas. The gravel was then cleaned in the summer of 1990 before the next adult spawning. A fry splitter was installed but no record of fry enumeration could be found. There are no reports of the channel being operated after 1990, but Levy and Lill (2008) noted that the Gwa'sala-'Nakwaxda'xw Nation provide stock assessment information as part of their Aboriginal Fisheries Strategy program.

Ron Goruk (pers. comm.) suggested the channel could be viable if funds were available for gravel cleaning and maintenance after flood events. In 2007, a site inspection by knowledgeable channel operators found the Nekite channel to be a good candidate for rehabilitation including improvements for coho rearing and modifications to the settling basin to reduce the frequency of cleaning operations (Levy and Lill 2008).

NuSEDS has records of chum and pink spawning in the channel from 1996 to 2010, with declining numbers after the mid-2000s. Ron Goruk (pers. comm.) was not aware of any on-site inspections in recent years, and noted that an overflight five or six years ago saw the intake plugged with no flow into the channel. Another flood and siltation event is known to have occurred in 2020.

## CHILKO RIVER SPAWNING CHANNEL

The Chilko spawning channel was constructed for sockeye in 1988. Located approximately two kilometres downstream of Chilko Lake, the channel benefited from stable flow and low sediment load from the lake, but the channel design lacked biological input and had several operational issues. Schubert and Fanos (1997) reported adults dying in the channel unspawned and suggested later opening and loading of the channel might reduce adult mortality. Brad Fanos (pers. comm.) noted that the channel needed to be managed, but the local DFO assessment crew was not available to regularly attend the channel, and a local person was eventually hired. General speculation is that lake spawners entering the channel would remain until dying unspawned.

Mel Sheng (pers. comm.) noted that a major problem was the approximate four-foot head drop at the top of the channel which prevented upstream migrating fry from exiting the channel and migrating to the lake. In addition, fry migrating upstream along the right bank of the river were unable to swim past the channel entrance and were diverted into the channel where their migration would be stopped. To remedy this, a fish lift was constructed. Fry were attracted into a container at the top end of the channel, a gate would then be closed and the water level in the container would rise to the same level as the river feeding the channel and allowing the fry to swim upstream. Two students were assigned to operate the lift throughout the fry migration. The channel exit was also stop logged and the outflow diverted through a pipe into the middle of the river so wild fry were not diverted into the channel.

The channel was eventually decommissioned and filled in. The date of decommissioning is not recorded. NuSEDS records spawners in the channel from 1988 to 1997. There are no records of fry production or egg-to-fry survival.

## GLENDALE RIVER SPAWNING CHANNEL

The Glendale pink channel was built in 1988. Located 2.6 kilometres upstream from the mouth of the Glendale River in Knight Inlet, it has the benefit of a clean and stable water supply from nearby Tom Browne Lake. The channel was originally overseen by staff from the Puntledge hatchery. Glendale channel has been more actively operated and assessed than the other unmanned spawning channels although there are many data gaps. Since 2006, staff from the Knight Inlet Lodge (KIL) have adjusted water flows for spawning and incubation and conducted fry enumeration programs in most years. Access to records has been limited by Covid restrictions, but available data from 1988 to 2019 has been summarized by Dave Ewart, retired hatchery manager (Appendix 18).

Adult and fry assessment programs from three of the first four brood years indicate the channel initially had very high egg-to-fry survivals averaging over 80 percent. However, after two decades without maintenance or gravel cleaning an inspection in 2007 by Vic Ewert, a highly experienced spawning channel operator, found several deficiencies including downstream movement of gravel leaving deep sections with little or no spawning gravel, stratified gravel with large cobble on top making it difficult for pink salmon spawners to build redds, large riprap armouring from the berms moved into and onto the spawning gravel, and the gravel was heavily silted with organic matter. In Ewert's opinion, "the conditions of the beds provides no greater egg-to-fry survival than found outside of the channel and may perhaps even be worse" (Ewert 2007a). A member of the public undertook to contract Ewert to oversee cleaning of the channel, which was done shortly after the inspection (Globe and Mail 2007). The gravel cleaning report provided 10 recommendations for improved operation, assessment and maintenance of the channel (Ewert 2007b). The gravel has not been cleaned since 2007.

Fry assessment in Glendale River and the channel has been conducted since 2007 by staff of the Knight Inlet Lodge who also adjust water flows in the spring and fall. Fry production from the channel has declined in recent years, but adult escapements to the Glendale system, and presumably to the channel, has been low which may have contributed to the lower fry numbers. However, the lack of spawner counts in the channel prevents calculation of egg-to-fry survival to monitor channel performance. NuSEDS reports only total escapements for the Glendale River system and does not provide separate counts for the channel.

Declining fry production has increased interest in the channel. A review in 2020 (Ewart 2020a) considered options to clean the spawning gravel or use hatchery technology to incubate eggs offsite and plant them back into the channel at the eyed stage. Considering the significant cost of gravel cleaning with no guarantee that adult escapement would be sufficient to fill the channel to capacity, the hatchery option was selected as more cost-effective. A pilot project was conducted to incubate eggs at the Puntledge River hatchery and plant the eyed eggs back into the channel in man-made redds or instream incubators. During the planting, the gravel was found to be silted with light organics with no evidence of inorganic silt or heavy compaction of the gravel (Ewart 2020b). Enumeration of spawners in the channel has not occurred in many years due to bear safety concerns but in 2020, KIL staff cut back vegetation to improve sight lines and used a drone to enumerate spawners. In addition, the channel entrance was modified to permit easier access for pink salmon, flow regulation in the channel was refined, and chum entry was permitted which will improve cleaning of the gravel that has been underutilized by pink salmon.

## KAKWEIKEN RIVER SPAWNING CHANNEL

The Kakweiken spawning channel, located on Thompson Sound north of Knight Inlet, was constructed in 1989 for pink salmon. The channel suffered from severe siltation and blockage of the channel intake caused by the flood prone river system. The Kakweiken River was described by Chamberlin et al. (1973) as high energy with frequent snow avalanches evidenced in alluvial deposits, while Rimmer and Axford (1990) noted flash flooding and bedload transport occur in response to heavy rainfall. In 2000, Williams et al. reported that the plugged intake had greatly reduced the available spawning area.

In 2008, site inspections by SEP Resource Restoration staff (Sheng et al. 2008) found two of the intake pipes blocked and the third greatly restricted while the settling basin was filled in and not functioning. Coho redds were observed in some areas of groundwater influence, but the majority of the channel was heavily silted and pink fry production appeared to be negligible. Options for redevelopment of the channel were set out. Gravel cleaning was not recommended unless many other improvements were made, including conversion to a semi-natural channel with improved intake reliability, sediment control, regrading to increase slope and regravelling with a mix of smaller gravel more suitable for pink spawners, other modifications, and recognition of the need for ongoing maintenance and operation.

Redevelopment of the Kakweiken spawning channel has not taken place. Jones and Beamish (2011) reported that "inspection of the channel in the spawning period in recent years did not detect any fish".

No published reports on channel operations or assessment were found, and NuSEDS does not identify the spawning channel as a separate component of the Kakweiken River system.

## ORFORD RIVER SPAWNING CHANNEL

The Orford spawning channel, located in Bute Inlet, was completed in 1990 to enhance the local chum population. There are no published reports on the Orford spawning channel and DFO's regional New Salmon Escapement Database System (NuSEDS) does not identify the spawning channel as a separate component of the Orford River system. Dave Ewart (pers. comm.) noted the channel was impacted by a slide in its first winter of operation. Ebell et al. (2009) reported that the channel was converted to rearing habitat in 2000-2002, and provided recommendations for ongoing maintenance of the channel intake and for additional habitat complexing improvements. Information on whether any recommendations had been acted upon or about the current state of the channel was not found.

# DISCUSSION

### Viability of fry from spawning channels

Fin clipping studies for BLDP sockeye (McDonald and Hume 1984) and Big Qualicum chum (Fraser et al. 1983) found channel and river origin fry respectively to have similar freshwater and marine survival rates.

### Egg-to-Fry Survival

Egg-to-fry survival in sockeye, pink and chum salmon spawning channels has averaged 50 percent, 52 percent and 53 percent, which is surprisingly similar to the assumed SEP biostandards of 1985 (Table 1). The apparent difference for chum is entirely due to the experimental Big Qualicum channel 1 which operated from 1963 to 1967.

Egg-to-fry survival in the Puntledge Chinook channel averaged 28 percent (MacKinnon et al. 1979). Annual survival was often around 40 percent or higher but the channel suffered from siltation and inadequate gravel cleaning which resulted in several years of low survival before the channel was repurposed for hatchery operations. No major spawning channel has been built since for Chinook in BC.

River flow control had mixed results. Review of the up-to-date information in this report found egg-to-fry survival did not increase at Fulton River but approximately doubled at Pinkut Creek. Development of the Big Qualicum River supplemented flow control with slope and channel modifications, gravel addition and ongoing gravel cleaning which has increased egg-to-fry survival by approximately 2.5 times.

Annual egg-to-fry survival in spawning channels has varied widely over their operational histories as seen by the wide confidence intervals and frequency distributions in Figure 50. The high variability is contributed to by many factors such as siltation and gravel cleaning, low flow or frazzle ice formation events in severe winter conditions, infrequent IHN outbreaks, and the accuracy of fry survival estimates.

**Table 1: Egg-to-fry survival (%) for sockeye, pink, chum and Chinook salmon spawning channels and rivers. Big Qualicum River Pre-Development egg-to-fry survival from Fraser (1983).**

<table>
<tr><th colspan="3">Average Egg-to-Fry Survival (%)</th><th>Sockeye</th><th>Pink</th><th>Chum</th><th>Chinook</th></tr>
<tr><td rowspan="8">Spawning Channels</td><td colspan="2">All Channels by Species</td><td>50.0%</td><td>51.8%</td><td>53.3%</td><td>28.2%</td></tr>
<tr><td>System</td><td>Channel (years)</td><td colspan="4"></td></tr>
<tr><td>Skeena</td><td>Fulton 2 (50)<br>Fulton 1 (41)<br>Pinkut (50)<br>avg</td><td>49.0%<br>36.5%<br>47.9%<br>44.5%</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Fraser</td><td>Nadina (48)<br>Horsefly (17)<br>Gates (48)<br>Weaver (56)<br>avg</td><td>51.2%<br>49.4%<br>54.0%<br>61.8%<br>54.1%</td><td></td><td></td><td></td></tr>
<tr><td>Upper Seton (19)<br>Lower Seton (16)<br>Jones (20)<br>Avg</td><td></td><td>52.2%<br>63.7%<br>39.4%<br>51.8%</td><td></td><td></td></tr>
<tr><td rowspan="2">South Coast</td><td>Big Qualicum 2 (44)<br>Big Qualicum 1 (5)<br>Little Qualicum (40)<br>avg</td><td></td><td></td><td>59.7%<br>39.5%<br>60.8%<br>53.3%</td><td></td></tr>
<tr><td>Puntledge (12)</td><td></td><td></td><td></td><td>28.2%</td></tr>
<tr><td colspan="2">SEP Biostandard 1985</td><td>50%</td><td>50%</td><td>60%</td><td>-</td></tr>
</table>

| Average Egg-to-Fry Survival (%) | | | Sockeye | Pink | Chum | Chinook |
|---|---|---|---|---|---|---|
| Rivers | Fulton River | Pre-Flow Control | 21% | | | |
| | | Flow Control | 18% | | | |
| | Pinkut Creek | Pre-Flow Control | 11% | | | |
| | | Flow Control | 25% | | | |
| | Weaver Creek | 1965-1984 | 7% | | | |
| | Gates Creek | IPSFC (estimate) | 15% | | | |
| | Fraser River | PSC 1961 – 1979 | | 14% | | |
| | | PSC 1981 – 2001 | | 7% | | |
| | Big Qualicum River | Pre-Development[1] | | | 14% | |
| | | Development | | | 32% | |
| | SEP Biostandard 1985 | Natural Rivers | 15% | 13% | 9% | 25% |

Photo by: Tavish Campbell

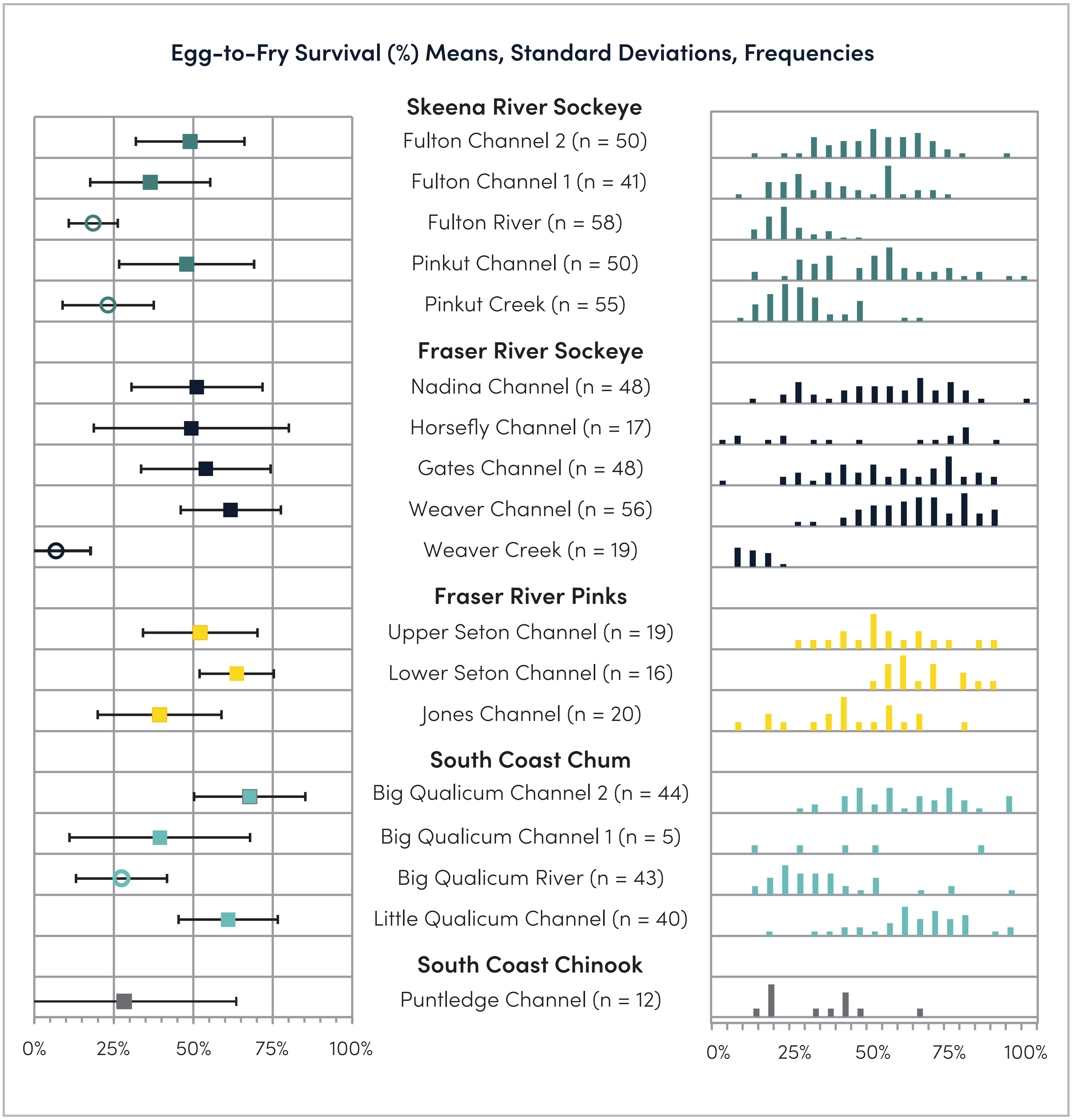



**Figure 50:** Mean egg-to-fry survival (%), 95% confidence intervals and frequency of Skeena sockeye spawning channels and flow controlled rivers, Fraser sockeye and pink spawning channels, and South Coast chum spawning channels (squares) and flow controlled river (hollow circles).

### Impacts to Egg-to-Fry Survival

Siltation is the most common factor affecting egg-to-fry survival, reducing intragravel permeability and water flow to incubating eggs and alevins. Egg-to-fry survival decreases over time unless the gravel environment is maintained. Gravel cleaning methods for major spawning channels have ranged from the most effective removal and replacement with washed gravel, to scarification with bulldozer buckets or excavators, cleaning with air-water jet cleaners, or the Babine rake, which rely on water flow through the channel to remove silt from the gravel while the gravel is moved. The air-water jet cleaners and the Babine rake have a tendency to stratify the gravel leaving larger cobble armouring the surface which can make it more difficult for spawners to build redds, but subsequent turning of the gravel with bulldozer or excavator buckets can remix the gravel to improve egg-to-fry survival further.

The Horsefly and Fulton 1 channels illustrate the effects of siltation and gravel cleaning. Egg-to-fry survival in the Horsefly channel averaged around 76 percent initially and for several years following each gravel replacement but declined to less than 20 percent after successive years without cleaning. Similarly, egg-to-fry survival in Fulton channel 1 declined after several years without gravel cleaning and was then restored to a range of 51 to 64 percent after gravel replacement. But the narrow Fulton channel 1 could only be cleaned by the less efficient Babine rake and survivals declined over several decades to levels around that of the adjacent river. The channel was eventually left to operate as a natural side channel.

To allow comparisons between channels, egg deposition per square metre (egg density) was used as a common metric and channels were grouped into Skeena sockeye, Fraser sockeye, Fraser pinks and South Coast chum channels (Fig. 51). Within the observed range of egg densities in major spawning channels, no significant relationships were found between egg-to-fry survival and egg deposition per square metre ($p>0.50$).

Significant linear relationships were found between fry production and egg deposition per square metre in all four groups of channels ($p<0.01$). In each group, the significance was not improved by non-linear functions and constraining the linear relationships through the origin was inconsequential.

These linear relationships are different from the trends that were observed in Fulton River (Fig. 27) and Pinkut Creek (Fig. 33) where lower egg-to-fry survival and fry production resulted from egg depositions that greatly exceeded the usual egg densities. This apparent difference is likely due to egg densities in channels being constrained by target spawning densities to a smaller range and are much lower than the highest spawning densities observed in rivers. The linear relationships observed in spawning channels should not be assumed to extend beyond the observed ranges.

Photo by: Eiko Jones


**Figure 51:** Left column: egg-to-fry survival (%); right column: fry production per square metre versus egg deposition per square metre, brood years within 1955 to 2020. Top row: Skeena River sockeye (blue diamond indicates Fulton 1, yellow triangle indicates Fulton 2, teal circle indicates Pinkut); second row: Fraser River sockeye (blue diamond indicates Nadina, yellow triangle indicates Gates, teal circle indicates Weaver); third row: Fraser River pink (blue diamond indicates Upper Seton, yellow triangle indicates Lower Seton, teal circle indicates Jones); bottom row: South Coast chum salmon spawning channels (blue circle indicates Big Qualicum 2, yellow triangle indicates Little Qualicum). Data for the plot is found in appendices 2, 4-7, 9-10, 12 and 14-17.

### Infectious Haematopoietic Necrosis (IHN)

The Infectious Haematopoietic Necrosis (IHN) virus is endemic in wild and enhanced sockeye stocks throughout the Pacific Northwest (Garver et al. 2022). The first epizootic in a wild stock was documented in Chilko Lake in 1973 (Williams and Amend 1976). Amongst all seven of the Fraser and Skeena River sockeye spawning channels, only three outbreaks have been recorded in 310 channel-years of operation, at Fulton channel 2 in 1984, Weaver channel in 1987 and Pinkut channel in 2021 which resulted in low to very low egg-to-fry survivals and fry production. However, fry mortality has been shown to occur up to four days after migration from the channel (Traxler and Rankin 1989) and the effect of an IHN outbreak may be more severe than reported by the fry enumeration programs. Factors that contribute to an IHN outbreak are not well understood. At Fulton and Pinkut, gravel cleaning and algal mats affecting intra-gravel conditions have been considered as contributing factors. At Weaver no unfavourable conditions such as low water flow or oxygen levels, or excessive algal growth were observed prior to the outbreak (Traxler and Rankin 1989; Garver et al. 2022).

### Prespawn Mortality

Prespawn mortality occurs naturally among adult escapements on spawning grounds and can have the immediate effect of reducing egg deposition and hence fry production. Hinch and Martins (2011) reviewing all Fraser run timing groups over a 70-year period found prespawn mortality to average ~ 10 percent, which is consistent with historic observation of PSM in most spawning channels.

Elevated prespawn mortality has had an increasingly significant impact on the Fraser and Skeena River sockeye spawning channels since the mid-1990s and appears related to high water temperatures and parasites. The three main parasites of concern are: "Ich" which is found in resident freshwater fish and picked up by returning salmon; the marine parasite "Loma" which is contracted by salmon during ocean migration; and, *Parvicapsula* which is contracted during migration through the lower Fraser River water column. These parasites are found in both wild and channel stocks but are perhaps observed more frequently in spawning channels because of their active operations.

Lofthouse (2017) summarized three factors that may contribute to parasite related PSM. High water temperature, which in itself can be a physiological stressor and increases the replication rate of parasites. Early freshwater entry or arrival time at the spawning grounds increases exposure time to Ich and *Parvicapsula*. And, escapement size can result in crowding and transmission of parasites behind enumeration fences like the Babine fence or control fences at channel exits. High spawning density may contribute to PSM but high PSM has also occurred at low spawning densities.

Lofthouse also describes several operational responses to reduce PSM. Rapid channel loading shortens the amount of time that adults are crowded behind channel fences. Terminal ESSR fisheries in Babine Lake also reduced the number of adults behind the Fulton and Pinkut fences. Spawning densities can be lowered below the target 1.25 square metres per female, particularly if in-season parasite monitoring has identified high parasite prevalence. Optimized spawning gravel encourages prompt spawning. Water temperature can be reduced at some facilities such as Pinkut and Nadina with deep lake-water intakes. And, where surplus spawners are available, lost fish can be replaced with later arriving spawners which may spawn successfully and replenish egg deposition. For example, Figure 32 shows that in two of four years with high PSM levels around 30 percent in Fulton channel 2, fry production was maintained at near normal levels.

Hinch et al. (2011) found no clear indication that PSM was increasing over a 70-year period by run- timing groups of Fraser River sockeye, except for late-run Cultus and Weaver sockeye, but noted that climate change forecasts of increasing temperatures will likely translate into a higher frequency of extreme prespawn mortality events for temperature sensitive stocks.

## Adult Production

Some major spawning channels have been very successful producers of salmon and supported significant fisheries, such as the Weaver Creek spawning channel and the Big Qualicum and Babine Lake Development Projects. Fishery effects of successful enhancement projects have received much attention where large numbers of enhanced fish can subject other stocks to increased harvest rates in mixed stock fisheries. Reduced harvest in marine interception fisheries including the terminal Qualicum Bay fishery to protect other stocks has led to the development of terminal harvests like the Babine Lake ESSR fishery or rack fisheries at the enhancement facilities. Weaver has contributed to the decline of the endangered Cultus Lake sockeye stock which in addition to pressures from changing environmental and habitat conditions, and mortality associated with changes in migration timing, has been subjected to increased harvest rates in mixed stock fisheries with the larger co-migrating Weaver and Adams River stocks (COSEWIC 2006, DFO 2018, DFO 2020).

The influence of ocean productivity and competition must be considered in assessments of adult production, particularly changes in ocean productivity over the long time period of channel operations which span more than half a century. Peterman's 1982 findings of a negative correlation between BLDP sockeye and dominant Skeena pink salmon years, which suggested the first 15 months of marine residence as the most critical and which disappeared after additional years of higher ocean productivity, serve as an illustration of variable effects of the ocean environment. Other examples include Wood's 2001 alternate hypothesis of a period of high ocean productivity masking over-exploitation of non-Babine stocks after 1990, and Hilborn's 1992 review that found pre- and post-channel assessments of Weaver sockeye was likewise influenced by a period of higher ocean productivity in post-channel years. Converse to Peterman's finding on the significance of the first 15 months of marine residence, Ruggerone and Connors (2015) found the abundance of pink salmon coincident with the second year of sockeye life in the North Pacific to be a contributing factor in the decline of sockeye productivity.

The increasing frequency of low escapements in recent years to the Weaver Creek system in spite of reduced exploitation rates since 2003 is notable. Although the channel has continued to produce fry at high egg-to-fry survival rates, low spawning escapements and numbers of effective spawners has resulted in historically low fry production. Low escapements are not confined to Weaver Creek. A COSEWIC (2017) assessment of Fraser River sockeye in 2017 found 10 of 22 Fraser sockeye stocks to be threatened or endangered, including stocks from all timing groups throughout the Fraser watershed. Overfishing, increased mortality associated with early up-river migration of late-run stocks, and lower marine survival were considered to have contributed to declines of these stocks. Harrison upstream migrant sockeye of which the Weaver spawning channel is the main producer were classified as endangered. The Anderson-Seton early summer run which includes Gates sockeye and the Nadina-Francois early summer run which includes Nadina channel fish were considered to be 'not at risk'.

Reduced harvest rates to protect weaker stocks in mixed stock fisheries have resulted in surplus escapements of channel stocks. Terminal harvests in ESSR fisheries in Babine Lake and 'rack' fisheries at channel sites like Big Qualicum and Weaver have reduced these surpluses in some years. However, there have also been increasingly frequent years of low adult returns, when even in the absence of commercial fisheries, escapements have been below the spawning targets, such as BLDP in 2013 and 2019, and Weaver in 2008, 2012, 2015, 2016, 2019 and 2020.

## Unmanned Channels

Fry and adult production from unmanned spawning channels has not been assessed. To minimize operating costs, fry and spawner enumeration programs were not conducted on unmanned channels. Glendale spawning channel is an exception where fry and spawner assessments were made in three of the first four years of operation, and fry assessments have been performed in recent years by Knight Inlet Lodge staff.

Of the six unmanned major spawning channels, Phillips, Orford and Nekite experienced catastrophic flood and siltation events, (Orford in its first winter of operation). Groundwater influence and restricted surface water supply support coho spawning in some sections of the Kakweiken channel, and the Chilko channel which suffered from lack of biological input to its design was eventually in-filled and decommissioned. Glendale is the only unmanned channel to have operated continuously. Egg-to-fry survival, initially high at over 80 percent, declined due to siltation and lack of gravel cleaning. The channel was cleaned once, in 2007. Fry production estimates have been made in most years since 2006 by KIL staff but lack of paired spawner and fry estimates does not allow egg-to-fry survival to be calculated.

## Status of Major Spawning Channels

Between 1954 and 1990, 22 major spawning channels were constructed in British Columbia to mitigate the loss of natural spawning grounds, to rebuild threatened stocks, or to increase adult production for harvest in fisheries. Currently, eight of the 22 channels are operating as per their original design, nine have been repurposed or modified for hatchery use, one is intact but currently not operated, three were severely impacted by floods events and one has been decommissioned (Table 2).

**Table 2: Summary and status of major artificial salmon spawning channels in British Columbia.**

| Spawning Channel | Primary Species | Years of Operation | Purpose | Operational Issues | Present Status |
|---|---|---|---|---|---|
| Jones | Pink | 1954 - 1993 | Mitigate loss of spawning habitat caused by hydro-electric development | Heavy siltation from floods in unstable watershed | Destroyed by flood in 1996 |
| Robertson | Pink/Coho Chinook | 1965 - 1976 | Pink transplants, coho and Chinook enhancement, research | Pink transplants not successful, coho spawner mortality, research studies concluded | Converted to hatchery rearing channels |
| Puntledge | Chinook | 1965 - 1976 | Mitigate loss of spawning habitat caused by hydro-electric development | Siltation, low numbers of spawners | Converted to hatchery rearing and holding channels |
| Upper Seton | Pink | 1961 - 1977 | Replace lost spawning habitat | No significant issues | Converted to semi-natural channel |
| Lower Seton | Pink | 1967 - 1997 | Replace lost spawning habitat | No significant issues | Converted to semi-natural channel |
| Weaver | Sockeye | 1965 - | Mitigate loss of productive spawning habitat | Low spawner escapements in recent years | Operational |
| Gates | Sockeye | 1968 - 2018 | Mitigate loss of productive spawning habitat | Decline in egg-to-fry survival in recent years, reason unknown | Intact, not operated |
| Nadina | Sockeye | 1973 - | Increase fry production for underutilized rearing capacity | Increasing frequency of elevated prespawn mortality | Operational |

| Spawning Channel | Primary Species | Years of Operation | Purpose | Operational Issues | Present Status |
|---|---|---|---|---|---|
| Fulton 1 | Sockeye | 1966 - 2010 | Increase fry production for underutilized rearing capacity | Long-term decline in egg-to-fry survival, channel is too narrow to use the more effective air/water jet gravel cleaner | Operated as a semi-natural channel |
| Fulton 2 | Sockeye | 1969 - | Increase fry production for underutilized rearing capacity | Increasing frequency of elevated prespawn mortality | Operational |
| Pinkut | Sockeye | 1968 - | Increase fry production for underutilized rearing capacity | Increasing frequency of elevated prespawn mortality | Operational |
| Big Qualicum 1 | Chum/ Coho Chinook | 1963 - 1968 | Experimental development for spawning channels | No significant issues | Converted to hatchery rearing channel |
| Big Qualicum 2 | Chum | 1967 - | Contribution to fisheries | No operational issues, low marine survival and spawning escapements in recent years | Operational |
| Little Qualicum | Chum | 1979 - | Contribution to fisheries | Heavy siltation requires ongoing gravel cleaning | Operational |
| Atnarko | Pink | 1986 - 1997 | Contribution to fisheries | Siltation | Converted to hatchery rearing ponds and semi-natural channel |
| Horsefly | Sockeye | 1979 - | Enhance off-cycle years of Horsefly sockeye | Siltation requires ongoing gravel cleaning | Operational – no operated in dominant cycle years |
| Phillips | Pink | 1984 – 2007? | Contribution to fisheries | Breaching and siltation events in 1988, 2000 and 2007 from nearby Wash Creek | Remnant not maintained, status unknown |
| Nekite | Chum | 1986 - mid-2000s | Contribution to fisheries | Heavy siltation and plugged intake from flood events, gravel cleaned once in 1990 | Not operational, plugged intake, no spawners observed in remnant channel |
| Chilko | Sockeye | 1988 – 1997? | Contribution to fisheries | Channel impeded upstream migration of fry and adults | Decommissioned |
| Glendale | Pink | 1988 - | Contribution to fisheries | No significant operational issues but only cleaned in 2007, likely lower egg survival | Operational |
| Kakweiken | Pink | 1989 - ? | Contribution to fisheries | Siltation and plugged intakes | Unattended, some use of groundwater sections by coho |
| Orford | Chum | 1990 - ? | Contribution to fisheries | Impacted by slide in first winter of operation | Converted to rearing habitat 2000 - 2002 |

## Potential for Future Development of Spawning Channels

Suitable locations for large scale spawning channels are limited, having significant requirements for clean and stable water supplies, and sizeable geography with suitable elevations adjacent to the spawning grounds of the target stock. A review of the SEP 1985 enhancement opportunities report (Lill et al. 1985) and 2008 enhancement scoping report (Lill et al. 2008) found relatively few good opportunities for new spawning channels. Better candidate projects particularly in light of changing hydrology from climate change involved other technologies such as water storage, gravel addition and stream rehabilitation (B. Shepherd pers. comm.). Other channel technologies generally built on smaller scales include groundwater-fed side channels for spawning and protected over-winter rearing habitat, and semi-natural channels that are complexed to enhance rearing habitat.

Technology for spawning channels has also developed, which might have improved the longer-term productivity of unmanned channels. Mel Sheng (pers. comm.) has offered the following thoughts on the design of unmanned spawning channels. The construction of major spawning channels intended to operate as unmanned channels was a misapplied technique. Major channels with clean lake fed water supplies and screened gravel were able to operate at low gradients because of the high porosity and permeability of the gravel. Survivals often exceeded or ranged between 50-70 percent. However, even these channels filled in with organic and inorganic fines that would combine to impact the flow of water through the eggs and required frequent cleaning. When this design was inappropriately used with river water supplies that experienced frequent silt laden flood events, the screened gravel clogged with glacial silt and sands smothering the redds and reducing hyporheic flow and oxygen.

To construct a low maintenance man-made channel, the intake must be designed to limit the amount of gravel and sand entering the channel (e.g. a pipe wing intake), incorporate a properly designed settling pond to settle out fines, use a spawning gravel mix that duplicates high quality natural gravel and must be installed at a much higher gradient (i.e. 0.25 to 0.5 percent) than the existing channels to keep fines moving downstream like in a natural creek. These types of channel maintain a survival rate closer to 30 percent. Not as good as the properly maintained SEP channels but still much better than wild survival rates which are usually less than 10 percent and may be lower in the future due to climate impacts.

Another design option is to build surface water channels at or below the low summer flow water table. The channel will generate groundwater when the river is in flood in the winter. If sufficient groundwater is generated it could be used as a temporary alternate supply if the surface supply is reduced or possibly even shut off. At Kakweiken, we proposed building a +500m groundwater channel which would connect to the top of the existing SEP channel and this could be used as an alternate supply when the river was in flood and dirty. New remote technology could incorporate a "valved" river intake that would automatically adjust flow depending on the river stage height. Secondary larger intakes could also be used to flush out the channel every few years.

Sheng's comments on groundwater influence are consistent with experience at the Weaver Creek spawning channel which was noted earlier as having a dynamic groundwater influence that is thought to have contributed to making it the most productive of the major spawning channels.


Photo by: Tavish Campbell

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Photo by: Eiko Jones

# APPENDICES

**Appendix 1. Design Specifications for Major Spawning Channels.**

| Location or Local Name | Year Built | Width (m) | Length (m) | Slope (%) | Velocity (m/s) | Area (m2) | Species | Design Capacity Females or Spawner Pairs | Gravel (in) Design Gradation | Water Supply | Channel Sediments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jones Creek | 1954 | 3.0 | 610 | .100 | 0.45 | 1,859 | Pink | 1,500 | .75 – 4 | River | Heavy Silt |
| Robertson Creek | 1960 | 10.7 | 792 | .160 | 0.86 | 8,453 | Chinook / Coho / Pink | 6,800 | .75 – 4 | Lake | - |
| Upper Seton Creek | 1961 | 6.1 | 826 | .060 | 0.38 | 5,033 | Pink | 6,700 | .50 – 4 | Siphon from lake-fed river | Minimal |
| Big Qualicum #1 | 1963 | 5.5 | 610 | .090 | 0.57 | 3,344 | Chum / Chinook | 2,700 | .75 – 4 | River | - |
| Pitt River (incubation channel) | 1963 | 1.8 | 370 | n/a | n/a | 677 | Sockeye | 3.3 M eggs | .75 – 4 | River | - |
| Weaver Creek | 1965 | 6.1 | 2,859 | .065 | 0.27 | 1,7429 | Sockeye | 13,900 | .50 – 4 | Intake on lake-fed creek | Silts organics |
| Fulton River #1 | 1965 | 9.1 | 1,250 | .090 | 0.44 | 11,426 | Sockeye | 9,100 | .50 – 4 | River d/s of Fulton dam | Fine silts |
| Puntledge River | 1965 | 7.6 | 244 | .100 | 0.49 | 1,858 | Chinook | 1,500 | .75 – 6 | River | Clay silts |
| Lower Seton Creek | 1967 | 6.1 | 2,865 | .100 | 0.44 | 17,462 | Pink | 23,300 | .50 – 4 | Siphon from lake-fed river | Minimal |
| Big Qualicum #2 | 1967 | 12.2 | 1,036 | .200 | 0.56 | 12,634 | Chum | 10,100 | .75 – 6 | River | Sand from river deposits |
| Gates Creek | 1968 | 5.9 | 1,850 | .050 | 0.31 | 10,995 | Sockeye | 8,800 | .50 – 4 | River & Pumped Lake Water | Silts / algae |
| Pinkut Creek | 1968 | 12.2 | 2,743 | .090 | 0.37 | 33,442 | Sockeye | 26,800 | .75 – 4 | River & Pumped Lake Water | Silts / algae |
| Fulton River #2 | 1969 – 1971 | 15.2 | 4,800 | .200 | 0.52 | 73,154 | Sockeye | 58,500 | .50 – 4 | Lake | Silts / algae |

| Location or Local Name | Year Built | Width (m) | Length (m) | Slope (%) | Velocity (m/s) | Area (m2) | Species | Design Capacity Females or Spawner Pairs | Gravel (in) Design Gradation | Water Supply | Channel Sediments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Nadina River | 1973 | 6.1 | 2,974 | .050 | 0.36 | 18,131 | Sockeye | 14,500 | .50 – 4 | Lake | Silts / algae |
| Little Qualicum | 1979 | 7.6 | 4,142 | .150 | 0.56 | 31,560 | Chum | 25,200 | .75 – 6 | River | Silts / algae |
| Phillips River | 1984 | 25.0 | 1,160 | .180 | 0.58 | 28,984 | Pink | 38,600 | .50 – 4 | Lake | Unknown |
| Nekite River | 1986 | 7.9 | 1,230 | .150 | 0.52 | 9,717 | Chum | 7,800 | .75 – 6 | River | Silts / sand |
| Atnarko | 1986 | 18.3 | 1,432 | .100 | 0.43 | 26,196 | Pink | 34,900 | .50 – 4 | River | - |
| Chilko River | 1988 | 12.0 | 792 | .050 | 0.38 | 9,504 | Sockeye | 7,600 | .50 – 4 | River d/s of lake | Glacial flour |
| Glendale River | 1988 | 15.0 | 1,334 | .090 | 0.42 | 20,010 | Pink | 26,700 | .50 – 4 | Lake | Fine silts / algae |
| Horsefly River | 1989 | 9.5 | 1,600 | .050 | 0.34 | 15,200 | Sockeye | 12,200 | .50 – 4 | River | Heavy silt in upper channel |
| Kakweiken River | 1989 | 13.3 | 1,760 | .090 | 0.41 | 23,408 | Pink | 31,200 | .50 – 4 | River | Unk |
| Orford River | 1990 | 15.0 | 1,020 | .100 | 0.53 | 15,300 | Chum | 12,200 | .75 – 6 | River | Heavy silt in upper channel |

**Appendix 2. Jones Channel and Creek pink salmon egg deposition, fry production and egg-to-fry survival (%), brood years 1955 to 2003.**

**Jones Channel Pink Salmon**
Spawning Area = 2,400 sq. m.

| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
|---|---|---|---|
| 1955 | 440,000 | 158,400 | 36.0% |
| 1957 | 1,130,000 | 364,600 | 32.3% |
| 1959 | 1,920,000 | 958,600 | 49.9% |
| 1961 | 3,970,000 | 1,055,200 | 26.6% |
| 1963 | 3,000,000 | 1,055,400 | 35.2% |
| 1965 | 2,400,000 | 1,267,800 | 52.8% |
| 1967 | 2,500,000 | 281,000 | 11.2% |
| 1969 | 1,100,000 | 145,700 | 13.2% |
| 1971 | 1,180,000 | 420,800 | 35.7% |
| 1973 | 1,680,000 | 593,700 | 35.3% |
| 1975 | 1,800,000 | 1,151,200 | 64.0% |
| 1977 | 1,870,000 | 943,900 | 50.5% |
| 1979 | 2,840,000 | 924,800 | 32.6% |
| 1981 | 1,990,000 | 1,574,900 | 79.1% |
| 1983 | 380,000 | 166,500 | 43.8% |
| 1985 | 2,390,000 | 465,500 | 19.5% |
| 1987 | 820,000 | 509,900 | 62.2% |
| 1989 | 4,230,000 | 2,134,500 | 50.5% |
| 1991 | 1,810,000 | 1,023,400 | 56.5% |
| 1993 | 80,000 | 1,000 | 1.3% |

**Jones Creek Pink Salmon**

| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
|---|---|---|---|
| 1955 | - | - | - |
| 1957 | 1,030,000 | 133,900 | 13% |
| 1959 | 400,000 | 52,000 | 13% |
| 1961 | 700,000 | 91,000 | 13% |
| 1963 | 740,000 | 96,200 | 13% |
| 1965 | 870,000 | 113,100 | 13% |
| 1967 | 760,000 | 98,800 | 13% |
| 1969 | 390,000 | 50,700 | 13% |
| 1971 | 620,000 | 80,600 | 13% |
| 1973 | 1,040,000 | 135,200 | 13% |
| 1975 | 540,000 | 70,200 | 13% |
| 1977 | 1,360,000 | 176,800 | 13% |
| 1979 | 570,000 | 74,100 | 13% |
| 1981 | 1,510,000 | 196,300 | 13% |
| 1983 | 620,000 | 81,100 | 13% |
| 1985 | 310,000 | 40,500 | 13% |
| 1987 | 590,000 | 76,300 | 13% |
| 1989 | 480,000 | 62,400 | 13% |
| 1991 | 1,730,000 | 225,300 | 13% |
| 1993 | 1,500,000 | 900 | 13% |

**Jones Channel Pink Salmon Egg Transplants**

| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
|---|---|---|---|
| 1954 | 2,606,000[a] | 1,100,00 | 42.2% |
| 1956 | 1,000,000[a] | - | - |
| " | 2,780,000[b] | - | - |
| " | | 321,000 | 8.5%[c] |
| 1988 | 36 adult return | - | - |

Reference: Fraser and Fedorenko (1983)
note a: eyed egg transplants from Lakelse, BC
note b: est. deposition from 2,800 adult returns
note c: severe winter conditions and sediment

***Jones Creek + Remnant Channel Pink Salmon***

| Brood Year | Spawners | Fry | E-t-F (%) Survival |
|---|---|---|---|
| 1999 | 1,380 | 7,160 | 0.4% |
| 2001 | 4,432 | - | - |
| 2003 | 2,489 | 5,702 | 0.3% |
| 2005 | 212 | 3,570 | 2.6% |
| 2007 | 3,167 | 86,442 | 3.5% |
| 2009 | 7,820 | 39,315 | 0.7% |
| 2011 | 7,569 | 119,249 | 2.2% |
| 2013 | 6,071 | 129,498 | 3.1% |

**Appendix 3. Puntledge Channel Chinook salmon egg deposition, fry production and egg-to-fry survival (%), brood years 1965 to 1976.**

| **Puntledge Channel Chinook**<br>Spawning Area = 1,905 sq. m. | | | |
|---|---|---|---|
| **Brood Year** | **Egg Deposition** | **Fry Production** | **E-t-F (%)Survival** |
| 1965 | 437,000 | 48,000 | 10.9% |
| 1966 | 211,000 | 84,000 | 39.9% |
| 1967 | 648,000 | 243,000 | 37.6% |
| 1968 | 415,000 | 186,000 | 45.0% |
| 1969 | 193,000 | 65,000 | 33.7% |
| 1970 | 853,000 | 213,000 | 26.1% |
| 1971 | 439,000 | 51,000 | 11.6% |
| 1972 | 527,000 | 67,000 | 12.7% |
| 1973 | 232,000 | 28,000 | 12.2% |
| 1974 | 122,000 | 9,800 | 8.1% |
| 1975 | 84,000 | 55,999 | 64.8% |
| 1976 | 15,000 | 5,422 | 36.3% |


Photo by: Eiko Jones

**Appendix 4. Upper and Lower Seton Channels pink salmon egg deposition, fry production and egg-to-fry survival (%), brood years 1961 to 1997.**

| Upper Seton Channel Pink Salmon<br>Spawning Area = 5,033 sq. m. | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 1961 | 6,813,000 | 3,592,000 | 52.7% |
| 1963 | 16,019,000 | 3,480,325 | 21.7% |
| 1965 | 7,768,000 | 2,681,000 | 34.5% |
| 1967 | 6,679,000 | 3,106,060 | 46.5% |
| 1969 | 4,602,000 | 2,743,394 | 59.6% |
| 1971 | 6,481,000 | 5,722,642 | 88.3% |
| 1973 | 7,325,000 | 5,477,202 | 74.8% |
| 1975 | 9,256,000 | 7,632,011 | 82.5% |
| 1977 | 15,150,000 | 7,205,863 | 47.6% |
| 1979 | 9,915,000 | 4,527,204 | 45.7% |
| 1981 | 11,006,000 | 3,876,788 | 35.2% |
| 1983 | 9,406,000 | 2,594,495 | 27.6% |
| 1985 | 4,158,294 | 1,497,735 | 36.0% |
| 1987 | 13,410,077 | 5,917,764 | 44.1% |
| 1989 | 16,900,000 | 10,756,487 | 63.6% |
| 1991 | 10,605,000 | 7,270,000 | 68.6% |
| 1993 | 8,746,000 | 4,299,172 | 49.2% |
| 1995 | 6,990,637 | 3,636,000 | 52.0% |
| 1997 | 6,473,000 | 3,978,000 | 61.5% |

| Lower Seton Channel Pink Salmon<br>Spawning Area = 17,462 sq. m. | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| – | – | – | – |
| – | – | – | – |
| – | – | – | – |
| 1967 | 19,174,000 | 8,977,364 | 46.8% |
| 1969 | 15,741,000 | 10,509,106 | 66.8% |
| 1971 | 22,369,000 | 12,770,044 | 57.1% |
| 1973 | 25,808,000 | 16,226,917 | 62.9% |
| 1975 | 24,483,000 | 16,326,756 | 66.7% |
| 1977 | 39,258,000 | 22,598,457 | 57.6% |
| 1979 | 33,445,000 | 18,594,881 | 55.6% |
| 1981 | 36,109,000 | 19,640,169 | 54.4% |
| 1983 | 31,063,000 | 15,574,510 | 50.1% |
| 1985 | 25,133,556 | 13,704,367 | 54.5% |
| 1987 | 37,164,296 | 24,252,747 | 65.3% |
| 1989 | 37,700,000 | 21,741,553 | 57.7% |
| 1991 | 25,621,000 | 21,945,000 | 85.7% |
| 1993 | 25,404,000 | 20,423,275 | 80.4% |
| 1995 | 23,094,041 | 18,008,334 | 78.0% |
| 1997 | 21,407,000 | 16,936,000 | 79.1% |

**Appendix 5. Weaver Channel and Creek sockeye egg deposition, fry production and egg-to-fry survival (%), brood years 1965 to 2020.**

| Weaver Channel Sockeye<br>Spawning Area = 17,429 sq. m.. | | | | Weaver Creek Sockeye | | | |
|---|---|---|---|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival | Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 1965 | 11,443,806 | 8,996,000 | 78.6% | 1965 | 17,758,000 | 1,475,010 | 8.3% |
| 1966 | 14,133,520 | 12,393,000 | 87.7% | 1966 | 28,353,000 | 2,100,000 | 7.4% |
| 1967 | 6,077,256 | 4,502,000 | 74.1% | 1967 | 38,486,000 | 2,500,000 | 6.5% |
| 1968 | 2,950,893 | 2,559,000 | 86.7% | 1968 | 5,987,000 | 1,025,000 | 17.1% |
| 1969 | 36,331,789 | 32,622,000 | 89.8% | 1969 | 82,626,000 | 4,510,000 | 5.5% |
| 1970 | 9,890,906 | 8,193,000 | 82.8% | 1970 | 11,457,000 | 1,650,000 | 14.4% |
| 1971 | 6,287,890 | 4,512,000 | 71.8% | 1971 | 4,809,000 | 720,000 | 15.0% |
| 1972 | 25,286,976 | 15,211,000 | 60.2% | 1972 | 34,682,000 | 4,191,000 | 12.1% |
| 1973 | 45,735,216 | 35,054,000 | 76.6% | 1973 | 61,171,000 | 3,763,000 | 6.2% |
| 1974 | 63,176,508 | 36,850,000 | 58.3% | 1974 | 66,454,000 | 6,777,000 | 10.2% |
| 1975 | 41,637,717 | 25,682,000 | 61.7% | 1975 | 26,615,000 | 279,000 | 1.0% |
| 1976 | 65,092,830 | 52,753,000 | 81.0% | 1976 | 53,019,000 | 4,825,000 | 9.1% |
| 1977 | 77,715,172 | 19,520,000 | 25.1% | 1977 | 46,189,000 | 339,000 | 0.7% |
| 1978 | 75,145,000 | 40,978,000 | 54.5% | 1978 | 109,983,000 | 2,069,000 | 1.9% |
| 1979 | 47,895,476 | 26,677,000 | 55.7% | 1979 | 62,006,000 | 359,000 | 0.6% |
| 1980 | 94,722,354 | 52,603,000 | 55.5% | 1980 | 79,893,000 | 400,000 | 0.5% |
| 1981 | 41,564,430 | 21,615,000 | 52.0% | 1981 | 51,431,000 | 5,598,000 | 10.9% |
| 1982 | 122,615,532 | 56,054,000 | 45.7% | 1982 | 361,854,000 | 2,590,000 | 0.7% |
| 1983 | 51,186,480 | 29,038,000 | 56.7% | 1983 | 67,533,000 | not available | 10.9% |
| 1984 | 97,513,662 | 45,400,000 | 46.6% | 1984 | 25,379,000 | 537,000 | 2.1% |
| 1985 | 43,959,141 | 18,880,000 | 42.9% | 1985 | - | - | - |
| 1986 | 84,608,016 | 19,144,000 | 22.6% | 1986 | - | - | - |
| 1987 | 78,424,892 | 33,773,000 | 43.1% | 1987 | - | - | - |
| 1988 | 57,039,044 | 20,437,000 | 35.8% | 1988 | - | - | - |
| 1989 | 27,971,065 | 21,663,000 | 77.4% | 1989 | - | - | - |
| 1990 | 21,757,710 | 18,219,000 | 83.7% | 1990 | - | - | - |
| 1991 | 56,663,919 | 42,913,000 | 75.7% | 1991 | - | - | - |
| 1992 | 64,791,585 | 46,090,000 | 71.1% | 1992 | - | - | - |
| 1993 | 61,980,462 | 38,820,000 | 62.6% | 1993 | - | - | - |
| 1994 | 67,515,448 | 42,218,000 | 62.5% | 1994 | - | - | - |
| 1995 | 31,707,117 | 21,962,000 | 69.3% | 1995 | - | - | - |
| 1996 | 68,647,704 | 45,048,000 | 65.6% | 1996 | - | - | - |
| 1997 | 38,312,736 | 13,703,000 | 35.8% | 1997 | - | - | - |
| 1998 | 63,535,648 | 47,767,000 | 75.2% | 1998 | - | - | - |
| 1999 | 40,623,000 | 30,929,000 | 76.1% | 1999 | - | - | - |
| 2000 | 8,684,000 | 6,569,000 | 75.6% | 2000 | - | - | - |

**Appendix 5. continued**

| Weaver Channel Sockeye Spawning Area = 17,429 sq. m.. | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 2001 | 31,319,000 | 21,243,000 | 67.8% |
| 2002 | 68,671,000 | 45,739,000 | 66.6% |
| 2003 | 67,194,000 | 45,230,000 | 67.3% |
| 2004 | 53,529,000 | 28,361,000 | 53.0% |
| 2005 | 69,568,000 | 33,922,000 | 48.8% |
| 2006 | 53,329,000 | 46,286,000 | 86.8% |
| 2007 | 46,866,000 | 28,494,000 | 60.8% |
| 2008 | 2,250,000 | 1,396,000 | 62.0% |
| 2009 | 44,567,000 | 34,236,000 | 76.8% |
| 2010 | 62,630,000 | 42,030,000 | 67.1% |
| 2011 | 67,125,000 | 36,959,000 | 55.1% |
| 2012 | 1,080,000 | 434,000 | 40.2% |
| 2013 | 55,065,000 | 35,430,000 | 64.3% |
| 2014 | 39,730,000 | 17,310,000 | 43.6% |
| 2015 | 3,430,000 | 1,733,000 | 50.5% |
| 2016 | 280,000 | 139,913 | 50.0% |
| 2017 | 37,830,000 | 24,800,000 | 65.6% |
| 2018 | 33,200,000 | 15,690,000 | 47.3% |
| 2019 | 3,770,000 | 1,970,000 | 52.3% |
| 2020 | 90,000 | 53,000 | 58.9% |

| Weaver Creek Sockeye | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 2001 | - | - | - |
| 2002 | - | - | - |
| 2003 | - | - | - |
| 2004 | - | - | - |
| 2005 | - | - | - |
| 2006 | - | - | - |
| 2007 | - | - | - |
| 2008 | - | - | - |
| 2009 | - | - | - |
| 2010 | - | - | - |
| 2011 | - | - | - |
| 2012 | - | - | - |
| 2013 | - | - | - |
| 2014 | - | - | - |
| 2015 | - | - | - |
| 2016 | - | - | - |
| 2017 | - | - | - |
| 2018 | - | - | - |
| 2019 | - | - | - |
| 2020 | - | - | - |

**Appendix 6. Gates Channel and Creek sockeye egg deposition, fry production and egg-to-fry survival (%), brood years 1968 to 2020.**

| Gates Channel Sockeye<br>Spawning Area = 10,995 sq. m. | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 1968 | 7,920,000 | 6,971,000 | 88.0% |
| 1969 | 919,000 | 334,000 | 36.3% |
| 1970 | 23,800 | 21,000 | 88.2% |
| 1971 | 258,000 | 216,000 | 83.7% |
| 1972 | 7,770,000 | 6,342,000 | 81.6% |
| 1973 | 2,366,000 | 1,793,000 | 75.8% |
| 1974 | 3,437,000 | 2,622,000 | 76.3% |
| 1975 | 3,472,000 | 2,137,000 | 61.5% |
| 1976 | 26,177,000 | 17,533,000 | 67.0% |
| 1977 | 2,602,000 | 1,898,000 | 72.9% |
| 1978 | 278,000 | 200,000 | 71.9% |
| 1979 | 5,110,000 | 2,896,000 | 56.7% |
| 1980 | 29,723,000 | 11,469,000 | 38.6% |
| 1981 | 5,927,000 | 4,028,000 | 68.0% |
| 1982 | 1,546,000 | 1,157,000 | 74.8% |
| 1983 | 9,427,000 | 5,622,000 | 59.6% |
| 1984 | 27,832,000 | 14,813,000 | 53.2% |
| 1985 | 5,901,000 | 3,619,000 | 61.3% |
| 1986 | 5,553,000 | 3,287,000 | 59.2% |
| 1987 | 11,095,000 | 5,679,000 | 51.2% |
| 1988 | 34,072,000 | 11,937,986 | 35.0% |
| 1989 | 27,509,000 | 11,630,828 | 42.3% |
| 1990 | 8,949,000 | 3,353,996 | 37.5% |
| 1991 | 13,641,000 | 6,606,087 | 48.4% |
| 1992 | 27,174,000 | 19,701,066 | 72.5% |
| 1993 | 27,347,000 | 12,364,811 | 45.2% |
| 1994 | 5,458,000 | 2,672,720 | 49.0% |
| 1995 | not operated | | |
| 1996 | 13,902,400 | 9,503,825 | 68.4% |
| 1997 | 5,787,200 | 4,340,113 | 75.0% |
| 1998 | 7,395,000 | 6,029,000 | 81.5% |
| 1999 | 5,553,600 | 4,165,200 | 75.0% |
| 2000 | 13,806,000 | 9,250,000 | 67.0% |
| 2001 | 11,618,000 | 6,390,000 | 55.0% |
| 2002 | 3,770,000 | 2,790,000 | 74.0% |
| 2003 | 14,520,000 | 5,810,000 | 40.0% |

| Gates Creek Sockeye | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 1968 | 4,497,000 | 674,550 | 15.0% |
| 1969 | 265,000 | 39,750 | 15.0% |
| 1970 | 24,000 | 3,600 | 15.0% |
| 1971 | 151,000 | 22,650 | 15.0% |
| 1972 | 3,106,000 | 465,900 | 15.0% |
| 1973 | 217,000 | 32,550 | 15.0% |
| 1974 | 11,000 | 1,650 | 15.0% |
| 1975 | 828,000 | 124,200 | 15.0% |
| 1976 | 5,029,000 | 754,350 | 15.0% |
| 1977 | 1,611,000 | 241,650 | 15.0% |
| 1978 | 165,000 | 24,750 | 15.0% |
| 1979 | 693,000 | 103,950 | 15.0% |
| 1980 | 4,682,000 | 702,300 | 15.0% |
| 1981 | 557,000 | 83,550 | 15.0% |
| 1982 | 93,000 | 13,950 | 15.0% |
| 1983 | 601,000 | 90,150 | 15.0% |
| 1984 | 1,716,000 | 257,400 | 15.0% |
| 1985 | no est. | 92,625 | - |
| 1986 | no est. | 87,763 | - |
| 1987 | no est. | 363,600 | - |
| 1988 | no est. | 3,925,200 | - |
| 1989 | no est. | 89,912 | - |
| 1990 | - | - | - |
| 1991 | - | - | - |
| 1992 | - | - | - |
| 1993 | - | - | - |
| 1994 | - | - | - |
| 1995 | - | - | - |
| 1996 | - | - | - |
| 1997 | - | - | - |
| 1998 | - | - | - |
| 1999 | - | - | - |
| 2000 | - | - | - |
| 2001 | - | - | - |
| 2002 | - | - | - |
| 2003 | - | - | - |

**Appendix 6. continued**

**Gates Channel Sockeye**
Spawning Area = 10,995 sq. m.

| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
|---|---|---|---|
| 2004 | 16,190,000 | 7,560,000 | 46.7% |
| 2005 | 24,556,800 | 5,785,000 | 23.6% |
| 2006 | 4,800,000 | 1,800,000 | 37.5% |
| 2007 | 3,047,268 | 1,500,000 | 49.2% |
| 2008 | not available | 1,650,000 | |
| 2009 | 8,864,000 | 3,600,000 | 40.6% |
| 2010 | 14,241,501 | 3,777,733 | 26.5% |
| 2011 | 16,831,380 | 5,515,083 | 32.8% |
| 2012 | 8,071,972 | 2,637,647 | 32.7% |
| 2013 | 17,910,156 | 2,845,029 | 15.6% |
| 2014 | 10,782,538 | 2,470,759 | 22.9% |
| 2015 | 11,204,544 | 3,364,877 | 30.0% |
| 2016 | not available | 53,315 | |
| 2017 | 3,497,000 | 545,000 | 15.6% |
| 2018 | 2,624,000 | 639,466 | 24.4% |
| 2019 | not operated | | |
| 2020 | not operated | | |

**Gates Creek Sockeye**

| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
|---|---|---|---|
| 2004 | - | - | - |
| 2005 | - | - | - |
| 2006 | - | - | - |
| 2007 | - | - | - |
| 2008 | - | - | - |
| 2009 | - | - | - |
| 2010 | - | - | - |
| 2011 | 69,428,220 | 10,214,909 | 14.7% |
| 2012 | 13,446,009 | 2,154,746 | 16.0% |
| 2013 | 59,797,356 | 12,738,610 | 21.3% |
| 2014 | 17,612,710 | 7,004,343 | 39.8% |
| 2015 | 19,807,344 | 6,682,451 | 33.7% |
| 2016 | 6,179,200 | - | - |
| 2017 | - | - | - |
| 2018 | 2,409,600 | - | - |
| 2019 | - | - | - |
| 2020 | - | - | - |

Photo by: Eiko Jones

**Appendix 7. Nadina Channel sockeye egg deposition, fry production and egg-to-fry survival (%), brood years 1973 to 2020.**

| Nadina Channel Sockeye<br>Spawning Area = 10,995 sq. m. | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 1973 | 13,360,000 | 9,906,000 | 74.1% |
| 1974 | 1,397,000 | 1,001,000 | 71.7% |
| 1975 | 18,881,000 | 12,113,000 | 64.2% |
| 1976 | 2,413,000 | 1,593,000 | 66.0% |
| 1977 | 28,039,000 | 14,213,000 | 50.7% |
| 1978 | 4,371,000 | 2,818,000 | 64.5% |
| 1979 | 41,349,000 | 19,162,000 | 46.3% |
| 1980 | 4,918,000 | 1,962,000 | 39.9% |
| 1981 | 30,688,000 | 16,504,000 | 53.8% |
| 1982 | 4,076,000 | 1,327,000 | 32.6% |
| 1983 | 43,601,000 | 18,052,000 | 41.4% |
| 1984 | 11,228,000 | 4,138,000 | 36.9% |
| 1985 | 20,102,000 | 6,007,000 | 29.9% |
| 1986 | 6,238,000 | 3,877,000 | 62.2% |
| 1987 | 39,054,000 | 17,607,000 | 45.1% |
| 1988 | 14,391,000 | 8,300,000 | 57.7% |
| 1989 | 7,400,000 | 1,746,000 | 23.6% |
| 1990 | 9,900,000 | 2,200,000 | 22.2% |
| 1991 | 78,661,000 | 16,353,000 | 20.8% |
| 1992 | 8,600,000 | 4,100,000 | 47.7% |
| 1993 | 9,000,000 | 1,847,000 | 20.5% |
| 1994 | 2,749,444 | 1,960,000 | 71.3% |
| 1995 | 15,960,185 | 1,200,000 | 7.5% |
| 1996 | 30,603,369 | 17,300,000 | 56.5% |
| 1997 | 2,410,256 | 400,000 | 16.6% |
| 1998 | 4,383,251 | 3,000,000 | 68.4% |
| 1999 | 10,668,456 | 3,200,000 | 30.0% |
| 2000 | 32,337,276 | 12,800,000 | 39.6% |
| 2001 | 31,916,412 | 12,900,000 | 40.4% |
| 2002 | 2,342,613 | 1,700,000 | 72.6% |
| 2003 | 1,576,304 | 1,500,000 | 95.2% |
| 2004 | 12,283,461 | 9,800,000 | 79.8% |
| 2005 | 16,782,056 | 7,300,000 | 43.5% |
| 2006 | 7,005,006 | 5,400,000 | 77.1% |

| Nadina Channel Sockeye<br>Continued | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 2007 | 1,724,433 | 1,100,000 | 63.8% |
| 2008 | 21,859,894 | 5,100,000 | 23.3% |
| 2009 | 4,512,074 | 3,500,000 | 77.6% |
| 2010 | 25,108,926 | 17,200,000 | 68.5% |
| 2011 | 2,395,449 | 1,000,000 | 41.7% |
| 2012 | 8,669,027 | 7,000,000 | 80.7% |
| 2013 | 11,011,709 | 6,600,000 | 59.9% |
| 2014 | 26,294,466 | 13,100,000 | 49.8% |
| 2015 | 10,252,400 | 7,540,000 | 73.5% |
| 2016 | 15,330,248 | 9,630,000 | 62.8% |
| 2017 | 2,979,998 | 1,500,000 | 50.3% |
| 2018 | 13,113,652 | 2,100,000 | 16.0% |
| 2019 | 3,578,352 | 2,313,520 | 64.7% |
| 2020 | 17,420,777 | 9,366,584 | 53.8% |

**Appendix 8. Fulton River sockeye egg deposition, fry production and egg-to-fry survival (%), brood years 1968 to 2020.**

**Fulton River (above fence) Sockeye**
Spawning Area = 62,700 sq. m. (high spawner use) plus 67,700 sq. m. (low to moderate use)

| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
|---|---|---|---|
| 1961 | 237,700,000 | 26,500,000 | 11.1% |
| 1962 | 136,500,000 | 41,700,000 | 30.5% |
| 1963 | 148,000,000 | 46,500,000 | 31.4% |
| 1964 | 187,000,000 | 24,500,000 | 13.1% |
| 1965 | 189,000,000 | 23,600,000 | 12.5% |
| 1966 | 77,500,000 | 24,000,000 | 31.0% |
| 1967 | 171,600,000 | 28,800,000 | 16.8% |
| 1968 | 213,600,000 | 38,700,000 | 18.1% |
| 1969 | 81,700,000 | 11,200,000 | 13.7% |
| 1970 | 189,900,000 | 38,900,000 | 20.5% |
| 1971 | 209,300,000 | 31,000,000 | 14.8% |
| 1972 | 167,400,000 | 33,400,000 | 20.0% |
| 1973 | 150,000,000 | 27,500,000 | 18.3% |
| 1974 | 131,500,000 | 27,700,000 | 21.1% |
| 1975 | 354,200,000 | 45,500,000 | 12.8% |
| 1976 | 289,300,000 | 57,000,000 | 19.7% |
| 1977 | 464,300,000 | 33,000,000 | 7.1% |
| 1978 | 85,400,000 | 33,600,000 | 39.3% |
| 1979 | 268,300,000 | 30,800,000 | 11.5% |
| 1980 | 93,900,000 | 32,300,000 | 34.4% |
| 1981 | 300,800,000 | 72,200,000 | 24.0% |
| 1982 | 337,400,000 | 43,100,000 | 12.8% |
| 1983 | 215,000,000 | 38,600,000 | 18.0% |
| 1984 | 269,700,000 | 41,300,000 | 15.3% |
| 1985 | 274,800,000 | 53,600,000 | 19.5% |
| 1986 | 137,900,000 | 40,300,000 | 29.2% |
| 1987 | 228,600,000 | 12,400,000 | 5.4% |
| 1988 | 403,900,000 | 38,900,000 | 9.6% |
| 1989 | 277,200,000 | 36,300,000 | 13.1% |
| 1990 | 206,200,000 | 34,023,000 | 16.5% |
| 1991 | 73,400,000 | 15,047,000 | 20.5% |
| 1992 | 175,800,000 | 26,721,600 | 15.2% |
| 1993 | 190,100,000 | 33,647,700 | 17.7% |
| 1994 | no estimate | 27,857,530 | 0.0% |

**Fulton River (above fence) Sockeye**
Continued

| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
|---|---|---|---|
| 1995 | no estimate | 21,938,730 | 0.0% |
| 1996 | 289,435,000 | 45,637,490 | 15.8% |
| 1997 | 202,692,000 | 62,429,136 | 30.8% |
| 1998 | 80,599,941 | 32,320,576 | 40.1% |
| 1999 | 112,378,933 | 27,195,702 | 24.2% |
| 2000 | 250,843,541 | 43,545,154 | 17.4% |
| 2001 | 323,821,991 | 55,485,809 | 17.1% |
| 2002 | 267,377,161 | 54,823,078 | 20.5% |
| 2003 | 549,601,450 | 45,910,530 | 8.4% |
| 2004 | 409,891,494 | 62,314,538 | 15.2% |
| 2005 | 241,965,175 | 44,308,446 | 18.3% |
| 2006 | 351,740,838 | 31,986,223 | 9.1% |
| 2007 | 414,748,662 | 39,825,848 | 9.6% |
| 2008 | 285,926,049 | 32,131,560 | 11.2% |
| 2009 | 257,747,050 | 37,492,522 | 14.5% |
| 2010 | 218,440,181 | 44,912,643 | 20.6% |
| 2011 | 393,820,938 | 59,463,827 | 15.1% |
| 2012 | 353,561,387 | 36,710,697 | 10.4% |
| 2013 | 97,654,759 | 14,070,077 | 14.4% |
| 2014 | 177,543,709 | 34,766,971 | 19.6% |
| 2015 | 230,944,313 | 41,041,944 | 17.8% |
| 2016 | 246,561,846 | 62,832,464 | 25.5% |
| 2017 | 240,760,248 | 33,612,023 | 14.0% |
| 2018 | 189,701,146 | 37,705,903 | 19.9% |
| 2019 | 159,533,259 | 30,689,510 | 19.2% |
| 2020 | 214,382,725 | 63,609,951 | 29.7% |

**Appendix 9. Fulton Channel 1 sockeye egg deposition, fry production and egg-to-fry survival (%), brood years 1968 to 2020.**

| Fulton Channel 1 Sockeye<br>Spawning Area = 10,000 sq. m. | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 1966 | 36,900,000 | 25,500,000 | 69.1% |
| 1967 | 32,800,000 | 16,000,000 | 48.8% |
| 1968 | 57,700,000 | 24,700,000 | 42.8% |
| 1969 | 27,800,000 | 5,900,000 | 21.2% |
| 1970 | 43,300,000 | 13,400,000 | 30.9% |
| 1971 | 39,400,000 | 20,000,000 | 50.8% |
| 1972 | 44,600,000 | 23,200,000 | 52.0% |
| 1973 | 34,300,000 | 15,000,000 | 43.7% |
| 1974 | 23,600,000 | 15,000,000 | 63.6% |
| 1975 | 23,600,000 | 12,700,000 | 53.8% |
| 1976 | 30,300,000 | 17,900,000 | 59.1% |
| 1977 | 27,400,000 | 14,300,000 | 52.2% |
| 1978 | 21,700,000 | 8,300,000 | 38.2% |
| 1979 | 28,300,000 | 9,000,000 | 31.8% |
| 1980 | 15,300,000 | 8,000,000 | 52.3% |
| 1981 | 23,700,000 | 12,300,000 | 51.9% |
| 1982 | 25,600,000 | 9,600,000 | 37.5% |
| 1983 | 28,900,000 | 5,900,000 | 20.4% |
| 1984 | 23,700,000 | 9,300,000 | 39.2% |
| 1985 | 20,300,000 | 5,200,000 | 25.6% |
| 1986 | 23,600,000 | 7,598,000 | 32.2% |
| 1987 | 25,300,000 | 2,835,000 | 11.2% |
| 1988 | 23,900,000 | 4,372,000 | 18.3% |
| 1989 | 22,600,000 | 11,975,000 | 53.0% |
| 1990 | 23,600,000 | 15,776,000 | 66.8% |
| 1991 | 18,000,000 | 13,437,000 | 74.7% |
| 1992 | 15,800,000 | 4,605,000 | 29.1% |
| 1993 | 31,700,000 | 3,700,000 | 11.7% |
| 1994 | no estimate | 15,100,000 | – |
| 1995 | no estimate | 3,726,345 | – |
| 1996 | no estimate | 1,326,852 | – |
| 1997 | 23,364,000 | 4,300,000 | 18.4% |
| 1998 | 13,390,625 | 6,700,000 | 50.0% |
| 1999 | 14,916,400 | 4,700,000 | 31.5% |
| 2000 | 16,120,012 | 2,084,645 | 12.9% |

| Fulton Channel 1 Sockeye<br>Continued | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 2001 | operated as part of river | | |
| 2002 | 6,788,628 | 1,448,962 | 21.3% |
| 2003 | 26,381,357 | 1,300,000 | 4.9% |
| 2004 | 10,796,297 | 1,296,194 | 12.0% |
| 2005 | 17,927,801 | 3,650,956 | 20.4% |
| 2006 | 21,668,906 | 4,547,543 | 21.0% |
| 2007 | 26,528,866 | 6,558,703 | 24.7% |
| 2008 | 10,226,872 | 6,633,570 | 64.9% |
| 2009 | 17,061,472 | 2,581,288 | 15.1% |
| 2010 | 20,591,031 | 3,240,238 | 15.7% |
| 2011 | ----- not operated ----- | | |
| 2012 | ----- not operated ----- | | |
| 2013 | ----- not operated ----- | | |
| 2014 | ----- not operated ----- | | |
| 2015 | operated as part of river | | |
| 2016 | operated as part of river | | |
| 2017 | operated as part of river | | |
| 2018 | operated as part of river | | |
| 2019 | operated as part of river | | |
| 2020 | operated as part of river | | |

**Appendix 10. Fulton Channel 2 sockeye egg deposition, fry production and egg-to-fry survival (%), brood years 1969 to 2020.**

| Fulton Channel 2 Sockeye<br>Spawning Area = 73,100 sq. m. | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 1969 | 35,000,000 | 25,400,000 | 72.6% |
| 1970 | 101,700,000 | 37,300,000 | 36.7% |
| 1971 | 175,200,000 | 82,200,000 | 46.9% |
| 1972 | 220,400,000 | 69,900,000 | 31.7% |
| 1973 | 168,700,000 | 75,000,000 | 44.5% |
| 1974 | 132,000,000 | 48,500,000 | 36.7% |
| 1975 | 171,600,000 | 68,600,000 | 40.0% |
| 1976 | 212,800,000 | 141,800,000 | 66.6% |
| 1977 | 207,100,000 | 84,000,000 | 40.6% |
| 1978 | 185,600,000 | 62,800,000 | 33.8% |
| 1979 | 201,400,000 | 91,500,000 | 45.4% |
| 1980 | 133,300,000 | 68,400,000 | 51.3% |
| 1981 | 198,100,000 | 53,300,000 | 26.9% |
| 1982 | 201,600,000 | 54,000,000 | 26.8% |
| 1983 | 191,800,000 | 14,000,000 | 7.3% |
| 1984 | 163,200,000 | 99,900,000 | 61.2% |
| 1985 | 155,300,000 | 83,400,000 | 53.7% |
| 1986 | 177,000,000 | 96,921,000 | 54.8% |
| 1987 | 190,300,000 | 44,269,000 | 23.3% |
| 1988 | 160,300,000 | 121,586,000 | 75.8% |
| 1989 | 165,000,000 | 87,075,000 | 52.8% |
| 1990 | 173,700,000 | 118,662,000 | 68.3% |
| 1991 | 136,400,000 | 82,812,000 | 60.7% |
| 1992 | 137,300,000 | 91,509,000 | 66.6% |
| 1993 | 142,400,000 | 70,400,000 | 49.4% |
| 1994 | no estimate | 33,559,218 | - |
| 1995 | no estimate | 22,160,076 | - |
| 1996 | 181,828,000 | 107,800,000 | 59.3% |
| 1997 | 131,666,000 | 22,500,000 | 17.1% |
| 1998 | 93,894,109 | 27,600,000 | 29.4% |
| 1999 | 75,843,741 | 19,600,000 | 25.8% |
| 2000 | 150,774,232 | 61,243,194 | 40.6% |
| 2001 | 151,240,918 | 92,159,331 | 60.9% |
| 2002 | 188,897,462 | 52,400,359 | 27.7% |
| 2003 | 175,982,495 | 118,661,737 | 67.4% |

| Fulton Channel 2 Sockeye<br>Continued | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 2004 | 176,224,370 | 104,247,632 | 59.2% |
| 2005 | 152,852,060 | 71,000,283 | 46.5% |
| 2006 | 145,177,838 | 68,733,110 | 47.3% |
| 2007 | 167,972,897 | 68,760,757 | 40.9% |
| 2008 | 157,391,488 | 100,608,099 | 63.9% |
| 2009 | 144,554,182 | 79,653,451 | 55.1% |
| 2010 | 130,777,377 | 96,420,745 | 73.7% |
| 2011 | 178,515,041 | 56,074,611 | 31.4% |
| 2004 | 176,224,370 | 104,247,632 | 59.2% |
| 2005 | 152,852,060 | 71,000,283 | 46.5% |
| 2006 | 145,177,838 | 68,733,110 | 47.3% |
| 2007 | 167,972,897 | 68,760,757 | 40.9% |
| 2008 | 157,391,488 | 100,608,099 | 63.9% |
| 2009 | 144,554,182 | 79,653,451 | 55.1% |
| 2010 | 130,777,377 | 96,420,745 | 73.7% |
| 2011 | 178,515,041 | 56,074,611 | 31.4% |
| 2012 | 179,334,117 | 97,500,000 | 54.4% |
| 2013 | 67,723,109 | 33,610,500 | 49.6% |
| 2014 | 146,663,851 | 94,479,802 | 64.4% |
| 2015 | 163,160,234 | 94,902,432 | 58.2% |
| 2016 | 147,601,873 | 95,397,777 | 64.6% |
| 2017 | 153,775,522 | 74,962,190 | 48.7% |
| 2018 | 143,407,006 | 135,062,265 | 94.2% |
| 2019 | 172,987,802 | 65,665,325 | 38.0% |
| 2020 | 136,239,503 | 79,635,711 | 58.5% |

**Appendix 11. Pinkut Creek sockeye egg deposition, fry production and egg-to-fry survival (%), brood years 1963 to 2020.**

**Pinkut Creek (fence to falls) Sockeye**
Spawning Area = 10,000 sq. m.

| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
|---|---|---|---|
| 1963 | 57,600,000 | 11,000,000 | 19.1% |
| 1964 | 255,700,000 | 4,500,000 | 1.8% |
| 1965 | 53,200,000 | 6,900,000 | 13.0% |
| 1966 | 24,800,000 | 3,700,000 | 14.9% |
| 1967 | 40,900,000 | 2,700,000 | 6.6% |
| 1968 | 19,000,000 | 1,900,000 | 10.0% |
| 1969 | 10,000,000 | 1,800,000 | 18.0% |
| 1970 | 16,500,000 | 3,300,000 | 20.0% |
| 1971 | 13,100,000 | 2,200,000 | 16.8% |
| 1972 | 21,500,000 | 3,000,000 | 14.0% |
| 1973 | 30,600,000 | 3,100,000 | 10.1% |
| 1974 | 30,700,000 | 3,000,000 | 9.8% |
| 1975 | 20,600,000 | 2,600,000 | 12.6% |
| 1976 | 35,700,000 | 8,100,000 | 22.7% |
| 1977 | 26,300,000 | 6,600,000 | 25.1% |
| 1978 | 8,284,021 | 2,239,275 | 27.0% |
| 1979 | 42,100,000 | 8,700,000 | 20.7% |
| 1980 | 31,700,000 | 10,800,000 | 34.1% |
| 1981 | 81,800,000 | 20,400,000 | 24.9% |
| 1982 | 118,100,000 | 28,500,000 | 24.1% |
| 1983 | 25,700,000 | 7,600,000 | 29.6% |
| 1984 | 69,600,000 | 14,300,000 | 20.5% |
| 1985 | 14,900,000 | 4,500,000 | 30.2% |
| 1986 | 25,300,000 | 14,371,000 | 56.8% |
| 1987 | 22,500,000 | 11,165,000 | 49.6% |
| 1988 | 30,200,000 | 6,010,000 | 19.9% |
| 1989 | 22,300,000 | 5,726,000 | 25.7% |
| 1990 | 23,700,000 | 14,380,000 | 60.7% |
| 1991 | 21,500,000 | 4,587,000 | 21.3% |
| 1992 | 37,090,000 | 6,023,000 | 16.2% |
| 1993 | 31,460,000 | 5,235,000 | 16.6% |
| 1994 | 14,733,649 | 6,808,557 | 46.2% |
| 1995 | 21,973,908 | 4,884,859 | 22.2% |
| 1996 | 24,509,466 | 3,242,347 | 13.2% |
| 1997 | 25,862,333 | 11,062,304 | 42.8% |
| 1998 | 28,219,260 | 16,586,884 | 58.8% |

**Pinkut Creek (fence to falls) Sockeye**
Continued

| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
|---|---|---|---|
| 1999 | 29,853,364 | 7,850,867 | 26.3% |
| 2000 | 25,700,000 | 11,460,000 | 44.6% |
| 2001 | 43,700,000 | 5,680,000 | 13.0% |
| 2002 | 28,590,000 | 5,680,000 | 19.9% |
| 2003 | 32,400,000 | 9,310,000 | 28.7% |
| 2004 | 37,422,437 | 23,920,526 | 63.9% |
| 2005 | 19,311,798 | 2,269,015 | 11.7% |
| 2006 | 17,369,440 | 2,562,495 | 14.8% |
| 2007 | 52,865,251 | 3,383,376 | 6.4% |
| 2008 | 25,082,144 | 6,650,730 | 26.5% |
| 2009 | 29,418,816 | 6,034,607 | 20.5% |
| 2010 | 27,234,399 | 2,941,722 | 10.8% |
| 2011 | 88,920,000 | 3,000,000 | 3.4% |
| 2012 | 28,000,000 | 3,800,000 | 13.6% |
| 2013 | 11,220,000 | 1,757,776 | 15.7% |
| 2014 | 28,290,000 | 1,760,000 | 6.2% |
| 2015 | 20,290,000 | 8,000,000 | 39.4% |
| 2016 | 113,732,782 | 28,660,661 | 25.2% |
| 2017 | not available | – | – |
| 2018 | not available | 4,086,948 | |
| 2019 | 46,000,000 | 8,967,063 | 19.5% |
| 2020 | not available | 713,138 | – |

**Appendix 12. Pinkut Channel sockeye egg deposition, fry production and egg-to-fry survival (%), brood years 1968 to 2020.**

| Pinkut Channel Sockeye<br>Spawning Area = 33,400 sq. m. | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 1968 | 30,800,000 | 10,400,000 | 33.8% |
| 1969 | 37,500,000 | 15,200,000 | 40.5% |
| 1970 | 37,900,000 | 22,000,000 | 58.0% |
| 1971 | 30,800,000 | 16,700,000 | 54.2% |
| 1972 | 96,600,000 | 29,000,000 | 30.0% |
| 1973 | 97,100,000 | 24,100,000 | 24.8% |
| 1974 | 93,400,000 | 8,300,000 | 8.9% |
| 1975 | 67,300,000 | 22,300,000 | 33.1% |
| 1976 | closed for reconstruction | | |
| 1977 | 99,500,000 | 53,600,000 | 53.9% |
| 1978 | 50,400,000 | 15,100,000 | 30.0% |
| 1979 | 92,900,000 | 47,500,000 | 51.1% |
| 1980 | 81,700,000 | 42,200,000 | 51.7% |
| 1981 | 69,600,000 | 57,700,000 | 82.9% |
| 1982 | 97,900,000 | 68,000,000 | 69.5% |
| 1983 | 97,700,000 | 49,900,000 | 51.1% |
| 1984 | 73,200,000 | 46,600,000 | 63.7% |
| 1985 | 74,400,000 | 35,900,000 | 48.3% |
| 1986 | 76,100,000 | 44,692,000 | 58.7% |
| 1987 | 78,300,000 | 19,062,000 | 24.3% |
| 1988 | 80,900,000 | 25,489,000 | 31.5% |
| 1989 | 69,400,000 | 11,165,000 | 16.1% |
| 1990 | 70,900,000 | 45,090,000 | 63.6% |
| 1991 | 78,010,000 | 40,295,000 | 51.7% |
| 1992 | 87,580,000 | 62,500,000 | 71.4% |
| 1993 | 81,310,000 | 25,060,000 | 30.8% |
| 1994 | 40,702,351 | 28,955,000 | 71.1% |
| 1995 | 60,560,154 | 17,602,000 | 29.1% |
| 1996 | 84,488,682 | 46,772,001 | 55.4% |
| 1997 | 69,662,000 | 31,600,000 | 45.4% |
| 1998 | 73,470,000 | 20,108,687 | 27.4% |
| 1999 | 78,233,902 | 39,200,000 | 50.1% |
| 2000 | 72,490,000 | 24,763,032 | 34.2% |
| 2001 | 93,000,000 | 77,497,733 | 25.3% |
| 2002 | 91,370,000 | 77,497,733 | 84.8% |
| 2003 | 81,500,000 | 74,184,800 | 91.0% |

| Pinkut Channel Sockeye<br>Continued | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 2004 | 82,411,184 | 79,810,890 | 96.8% |
| 2005 | 76,641,437 | 53,353,025 | 69.6% |
| 2006 | 76,641,437 | 53,353,025 | 69.6% |
| 2007 | 88,362,016 | 68,303,838 | 77.3% |
| 2008 | 76,957,902 | 37,803,360 | 49.1% |
| 2009 | 78,400,476 | 37,801,410 | 48.2% |
| 2010 | 89,022,272 | 37,970,834 | 42.7% |
| 2011 | 64,000,206 | 38,000,000 | 59.4% |
| 2012 | 96,177,744 | 20,554,713 | 21.4% |
| 2013 | 20,450,000 | 4,926,559 | 24.1% |
| 2014 | 63,460,000 | 4,930,000 | 7.8% |
| 2015 | 70,550,000 | 31,900,000 | 45.2% |
| 2016 | 79,153,049 | 35,381,413 | 44.7% |
| 2017 | not available | | |
| 2018 | not available | 48,446,786 | - |
| 2019 | 68,000,000 | 47,619,609 | 70.0% |
| 2020 | 50,800,000 | 10,467,934 | 20.6% |

**Appendix 13. Big Qualicum River chum salmon egg deposition, fry production and egg-to-fry survival (%), brood years 1961 to 1997.**

| Big Qualicum River Chum<br>Surface Area = 17,462 sq. m. | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 1959 | 94,300,000 | 17,900,000 | 19.0% |
| 1960 | 63,060,000 | 3,600,000 | 5.7% |
| 1961 | 17,060,000 | 3,400,000 | 20.2% |
| 1962 | 52,430,000 | 5,100,000 | 9.8% |
| 1963 | 43,530,000 | 15,000,000 | 34.6% |
| 1964 | 37,730,000 | 10,800,000 | 28.5% |
| 1965 | 14,670,000 | 7,100,000 | 48.1% |
| 1966 | 58,640,000 | 17,600,000 | 30.0% |
| 1967 | 27,960,000 | 12,900,000 | 46.9% |
| 1968 | 173,200,000 | 28,100,000 | 16.4% |
| 1969 | 109,600,000 | 32,000,000 | 30.7% |
| 1970 | 136,100,000 | 20,900,000 | 15.6% |
| 1971 | 103,300,000 | 14,000,000 | 13.7% |
| 1972 | 48,180,000 | 12,900,000 | 26.8% |
| 1973 | 242,016,807 | 28,800,000 | 11.9% |
| 1974 | 87,660,668 | 34,100,000 | 38.9% |
| 1975 | 130,588,235 | 33,300,000 | 25.5% |
| 1976 | 113,580,247 | 27,600,000 | 24.3% |
| 1977 | 112,396,694 | 27,200,000 | 24.2% |
| 1978 | 155,801,105 | 28,200,000 | 18.1% |
| 1979 | 152,307,692 | 29,700,000 | 19.5% |
| 1980 | 89,473,684 | 34,000,000 | 38.0% |
| 1981 | not available | not available | – |
| 1982 | not available | not available | – |
| 1983 | 110,248,352 | 26,834,556 | 24.3% |
| 1984 | not available | not available | - |
| 1985 | 60,394,397 | 8,598,100 | 14.2% |
| 1986 | not available | | |
| 1987 | not available | | |
| 1988 | not available | | |
| 1989 | not available | | |
| 1990 | not available | | |
| 1991 | not available | | |
| 1992 | not available | | |
| 1993 | 93,443,073 | 42,665,142 | 45.7% |
| 1994 | 102,354,791 | 27,817,632 | 27.2% |

| Big Qualicum River Chum<br>Continued | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 1995 | 11,882,576 | 10,789,115 | 90.8% |
| 1996 | 22,983,957 | 7,347,664 | 32.0% |
| 1997 | 26,788,488 | 19,055,141 | 71.1% |
| 1998 | 139,988,551 | 31,247,678 | 22.3% |
| 1999 | 19,419,367 | 14,139,743 | 72.8% |
| 2000 | 8,503,450 | 5,371,923 | 63.2% |
| 2001 | 105,775,359 | 33,488,996 | 31.7% |
| 2002 | 67,885,643 | 23,220,469 | 34.2% |
| 2003 | not available | 11,826,149 | – |
| 2004 | not available | 10,589,346 | – |
| 2005 | 21,226,113 | 9,643,376 | 45.4% |
| 2006 | 51,274,285 | 8,030,136 | 15.7% |
| 2007 | 9,816,446 | 4,056,905 | 41.3% |
| 2008 | 4,244,860 | 719,554 | 17.0% |
| 2009 | 12,187,309 | 1,462,745 | 12.0% |
| 2010 | not available | 865,466 | – |
| 2011 | not available | 17,383,807 | – |
| 2012 | not available | 17,684,925 | – |
| 2013 | not available | 10,103,582 | – |
| 2014 | 7,463,706 | 1,464,113 | 19.6% |
| 2015 | 19,799,641 | 9,264,444 | 46.8% |
| 2016 | 117,499,037 | 13,962,715 | 11.9% |
| 2017 | 6,792,773 | not available | |
| 2018 | 6,629,025 | 815,065 | 12.3% |
| 2019 | 890,000 | not available | |
| 2020 | not available | | |

**Appendix 14. Big Qualicum Channel 1 chum salmon egg deposition, fry production and egg-to-fry survival (%), brood years 1961 to 1997.**

| Big Qualicum Channel 1 Chum<br>Surface Area = 2,800 sq. m. | | | |
|---|---|---|---|
| **Brood Year** | **Egg Deposition** | **Fry Production** | **E-t-F (%)Survival** |
| 1963 | 3,750,000 | 1,780,000 | 47.6% |
| 1964 | 1,580,000 | 100,000 | 6.6% |
| 1965 | 2,800,000 | 690,000 | 24.8% |
| 1966 | 3,190,000 | 1,140,000 | 35.8% |
| 1967 | 680,000 | 560,000 | 82.5% |
| 1968 | – | – | – |
| 1969 | 650,000 | not recorded | not recorded |

Photo by: Jeremy Koreski

**Appendix 15. Big Qualicum Channel 2 chum salmon egg deposition, fry production and egg-to-fry survival (%), brood years 1961 to 1997.**

**Big Qualicum Channel 2 Chum**
Surface Area 1967 = 12,000 sq. m.
" 1968 = 13,000 "
" 1969 = 13,000 "
" 1970 onwards = 14,000 sq. m.

| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
|---|---|---|---|
| 1967 | 12,970,000 | 11,700,000 | 90.1% |
| 1968 | 22,000,000 | 17,600,000 | 80.1% |
| 1969 | 27,300,000 | 20,900,000 | 76.4% |
| 1970 | 33,710,000 | 20,400,000 | 60.6% |
| 1971 | 23,980,000 | 17,500,000 | 72.9% |
| 1972 | 33,560,000 | 22,500,000 | 67.0% |
| 1973 | 31,978,320 | 23,600,000 | 73.8% |
| 1974 | 28,871,391 | 22,000,000 | 76.2% |
| 1975 | 33,771,930 | 23,100,000 | 68.4% |
| 1976 | 41,873,805 | 21,900,000 | 52.3% |
| 1977 | 38,041,002 | 16,700,000 | 43.9% |
| 1978 | 43,448,276 | 12,600,000 | 29.0% |
| 1979 | 35,294,118 | 25,200,000 | 71.4% |
| 1980 | 37,500,000 | 27,000,000 | 72.0% |
| 1981 | not available | | |
| 1982 | not available | | |
| 1983 | 34,460,316 | 24,325,002 | 70.6% |
| 1984 | not available | | |
| 1985 | 30,949,469 | 13,393,473 | 43.3% |
| 1986 | not available | | |
| 1987 | not available | | |
| 1988 | not available | | |
| 1989 | not available | | |
| 1990 | not available | | |
| 1991 | not available | | |
| 1992 | not available | | |
| 1993 | 39,949,877 | 14,950,812 | 37.4% |
| 1994 | 33,930,279 | 15,038,066 | 44.3% |
| 1995 | 9,732,205 | 4,290,139 | 44.1% |
| 1996 | 1,723,003 | 414,070 | 24.0% |
| 1997 | 15,039,988 | 8,186,202 | 54.4% |
| 1998 | 32,804,527 | 14,851,799 | 45.3% |
| 1999 | 13,261,068 | 9,776,509 | 73.7% |

**Big Qualicum Channel 2 Chum**
Continued

| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
|---|---|---|---|
| 2000 | 1,474,626 | 931,572 | 63.2% |
| 2001 | 24,040,283 | 9,492,882 | 39.5% |
| 2002 | 21,230,619 | 11,883,649 | 56.0% |
| 2003 | 21,743,067 | 10,908,216 | 50.2% |
| 2004 | 18,124,284 | 12,561,830 | 69.3% |
| 2005 | 8,507,504 | 7,656,754 | 90.0% |
| 2006 | 20,198,530 | 21,706,630 | 107.5% |
| 2007 | 18,929,340 | 9,753,741 | 51.5% |
| 2008 | 17,532,396 | 8,032,283 | 45.8% |
| 2009 | 20,310,625 | 10,763,516 | 53.0% |
| 2010 | 9,012,802 | 5,586,145 | 62.0% |
| 2011 | 29,433,528 | 10,854,217 | 36.9% |
| 2012 | 24,635,125 | 10,586,791 | 43.0% |
| 2013 | 21,026,238 | 8,336,646 | 39.6% |
| 2014 | 14,875,576 | 4,333,721 | 29.1% |
| 2015 | 29,081,154 | 12,919,520 | 44.4% |
| 2016 | 31,149,028 | 28,213,058 | 90.6% |
| 2017 | 16,031,615 | 14,676,938 | 91.5% |
| 2018 | 3,484,431 | 2,642,746 | 75.8% |
| 2019 | 1,400,000 | 890,000 | 63.6% |
| 2020 | 10,994,336 | 5,818,698 | 52.9% |

**Appendix 16. Little Qualicum Channel chum salmon egg deposition, fry production and egg-to-fry survival (%), brood years 1961 to 1997.**

| Little Qualicum Channel Chum Surface Area = 31,560 sq. m. | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 1979 | 6,914,575 | 6,060,526 | 87.6% |
| 1980 | 8,445,400 | 7,626,715 | 90.3% |
| 1981 | 5,680,686 | 4,194,716 | 73.8% |
| 1982 | 41,294,682 | 25,620,083 | 62.0% |
| 1983 | 46,240,545 | 21,725,000 | 47.0% |
| 1984 | 58,126,000 | 24,354,211 | 41.9% |
| 1985 | 83,036,615 | 9,625,786 | 11.6% |
| 1986 | 66,270,536 | 44,065,986 | 66.5% |
| 1987 | 69,307,884 | 39,425,391 | 56.9% |
| 1988 | 61,512,239 | 37,499,428 | 61.0% |
| 1989 | 42,691,230 | 28,014,413 | 65.6% |
| 1990 | 69,908,128 | 42,638,748 | 61.0% |
| 1991 | 56,626,470 | 32,104,043 | 56.7% |
| 1992 | 75,000,000 | 42,467,708 | 56.6% |
| 1993 | 49,707,377 | 30,550,740 | 61.5% |
| 1994 | 53,932,087 | 31,937,880 | 59.2% |
| 1995 | 21,347,455 | 11,041,160 | 51.7% |
| 1996 | 13,624,000 | 8,936,760 | 65.6% |
| 1997 | 25,944,901 | 9,424,480 | 36.3% |
| 1998 | 55,103,246 | 15,860,360 | 28.8% |
| 1999 | 31,675,024 | 12,766,000 | 40.3% |
| 2000 | 9,839,232 | 5,817,520 | 59.1% |
| 2001 | 33,250,000 | 22,029,734 | 66.3% |
| 2002 | 31,923,199 | 11,191,500 | 35.1% |
| 2003 | 38,000,000 | 12,927,540 | 34.0% |
| 2004 | 31,357,300 | 28,972,400 | 92.4% |
| 2005 | 16,774,282 | 9,865,420 | 58.8% |
| 2006 | 34,886,820 | 23,886,500 | 68.5% |
| 2007 | 29,954,043 | 21,720,120 | 72.5% |
| 2008 | 28,969,676 | 14,774,280 | 51.0% |
| 2009 | 24,562,128 | 14,341,780 | 58.4% |
| 2010 | 10,153,806 | 7,721,140 | 76.0% |
| 2011 | 40,928,350 | 31,579,920 | 77.2% |
| 2012 | 41,131,609 | 31,175,740 | 75.8% |
| 2013 | 29,003,293 | 23,121,060 | 79.7% |
| 2014 | 5,445,848 | 4,247,761 | 78.0% |

| Little Qualicum Channel Chum Continued | | | |
|---|---|---|---|
| Brood Year | Egg Deposition | Fry Production | E-t-F (%) Survival |
| 2015 | 35,612,401 | 17,938,440 | 50.4% |
| 2016 | 61,680,613 | 45,304,800 | 73.5% |
| 2017 | 6,029,551 | 4,522,163 | 75.0% |
| 2018 | 7,083,792 | 4,910,020 | 69.3% |
| 2019 | not available | | |
| 2020 | 10,910,073 | not available | |

**Appendix 17. Horsefly Channel sockeye egg deposition, fry production and egg-to-fry survival (%), brood years 1997 to 2019.**

| **Horsefly Channel Sockeye**<br>Surface Area = 15,200 sq. m. | | | |
|---|---|---|---|
| **Brood Year** | **Egg Deposition** | **Fry Production** | **E-t-F (%)Survival** |
| 1989 | 32,900,000 | 25,800,000 | 78.4% |
| 1990 | 28,100,000 | 18,000,000 | 64.1% |
| 1991 | 34,750,000 | 22,630,000 | 65.1% |
| 1992 | 3,010,000 | 2,370,000 | 78.7% |
| 1993 | 23,120,000 | 3,570,000 | 15.4% |
| 1994 | 24,610,000 | 850,000 | 3.5% |
| 1995 | 23,420,000 | 8,000,000 | 34.2% |
| 1996 | 17,430,000 | 1,930,000 | 11.1% |
| 1997 | ----- not operated ----- | | |
| 1998 | 22,520,000 | 16,820,000 | 74.7% |
| 1999 | 27,210,000 | 23,700,000 | 87.1% |
| 2000 | 1,820,000 | 1,360,000 | 74.7% |
| 2001 | ----- not operated ----- | | |
| 2002 | 37,510,000 | 29,400,000 | 78.4% |
| 2003 | 31,920,000 | 25,500,000 | 79.9% |
| 2004 | ----- not operated ----- | | |
| 2005 | ----- not operated ----- | | |
| 2006 | 29,530,000 | 5,200,000 | 17.6% |
| 2007 | 5,600,000 | no fry estimate | |
| 2008 | ----- not operated ----- | | |
| 2009 | 11,100,000 | 3,300,000 | 29.7% |
| 2010 | 34,570,000 | 1,560,000 | 4.5% |
| 2011 | 3,140,000 | no fry estimate | |
| 2012 | ----- not operated ----- | | |
| 2013 | ----- not operated ----- | | |
| 2014 | 23,470,000 | 10,000,000 | 42.6% |
| 2015 | 4,315 spawners | | |
| 2016 | ----- not operated ----- | | |
| 2017 | no record available | | |
| 2018 | 895 spawners | no fry estimate | |
| 2019 | 22 spawners | no fry estimate | |
| 2020 | ----- not operated ----- | | |

**Appendix 18. Glendale Spawning Channel pink fry production, female spawners, and egg-to-fry survival (%), brood years 1998 to 2019.**

| Brood Year | Fry Production | Estimated Female Spawners | Estimated Egg Deposition | Estimated Egg-to-Fry Survival (%) | Comments |
|---|---|---|---|---|---|
| 1998 | 19,462,689 | 22,620 | 23,958 | 81% | Puntledge Staff |
| 1999 | | | | | N/D |
| 2000 | 38,533,361 | 32,800 | 45,940,000 | 84% | Triton Env. |
| 2001 | 7,280,840 | 5,677 | 8,300,000 | 88% | Tanakteuk First Nation |
| 2002 | | | | | N/D |
| 2003 | | | | | N/D |
| 2004 | | | | | N/D |
| 2005 | | | | | N/D |
| 2006 | 7,837,598 | | | | Glendale Lodge, fry only |
| 2007 | 4,585,434 | | | | Glendale Lodge, fry only |
| 2008 | 3,760,104 | | | | Glendale Lodge, fry only |
| 2009 | 18,587,018 | | | | Glendale Lodge, fry only |
| 2010 | 3,757,877 | | | | Glendale Lodge, fry only |
| 2011 | 1,985,342 | | | | Glendale Lodge, fry only |
| 2012 | | | | | N/D |
| 2013 | | | | | N/D |
| 2014 | | | | | N/D |
| 2015 | 510,160 | | | | Glendale Lodge, fry only |
| 2016 | 3,951,880 | | | | Glendale Lodge, fry only |
| 2017 | 7,120 | | | | Glendale Lodge, fry only |
| 2018 | 440,820 | | | | Glendale Lodge, fry only |
| 2019 | | | | | N/D |

Photo by: Tavish Campbell

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