an upstream battle

DECLINES IN 10 PACIFIC SALMON STOCKS AND SOLUTIONS FOR THEIR SURVIVAL

David Suzuki Foundation

SOLUTIONS ARE IN OUR NATURE

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An Upstream Battle: Declines in 10 Pacific salmon stocks and solutions for their survival

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FOREWORD FROM THE DAVID SUZUKI FOUNDATION

The David Suzuki Foundation is actively working to ensure Pacific salmon remain a vital component of Canada's West Coast ecosystems. To highlight areas of concern and identify solutions to problems, the Foundation regularly commissions scientific assessments related to salmon and other species.

This report is being released at a critical time for Pacific salmon in Canada. The federal government is in the early stages of implementing its Wild Salmon Policy (www-comm.pac.dfo-mpo.gc.ca/pages/consultations/wsp/default_e.htm), which provides a template for ensuring the long-term health of Pacific salmon. However, a lack of political and financial support means this important policy could end up as just another piece of paper. Despite some strong efforts by its staff, the government has yet to show any real action that will benefit wild salmon.

Wild salmon fisheries are also facing pressure from the marketplace to show they are sustainable. The Marine Stewardship Council, an international certification body, is about to decide whether to give a sustainability stamp of approval to four B.C. sockeye salmon fisheries. The poor status of salmon detailed in this report, and the role fisheries play in many of the declines, call into question whether B.C. salmon fisheries are sustainable. To meet certification criteria, the management agency must ensure that measures are taken to protect and rebuild depleted stocks and fisheries are prevented from causing similar declines in the future.

The David Suzuki Foundation is working on many fronts to ensure that government policies are strong and well implemented and that efforts to certify fish for the marketplace are meaningful and truly support the long-term health of wild salmon.

We investigate habitat status and demand the enforcement of laws. (See *The Will to Protect* and *High and Dry* at www.davidsuzuki.org.)

We participate in salmon fisheries management, including the Integrated Harvest Planning Committee and the Fraser River Panel of the Pacific Salmon Treaty.

We comment on certification reports and work with the certifiers to improve their standards.

We worked to ensure that the Wild Salmon Policy was strong, and are now working to ensure it is effectively implemented with the money and political backing it needs.

The declines of salmon profiled in this report are symptomatic of the challenges facing Pacific salmon in Canada. By focusing on specific examples of salmon stocks or populations in decline, this report analyzes these challenges in greater detail and provides guidance on recovery. Pacific salmon on a broader scale, across many populations and regions, also face these challenges. Returns of sockeye salmon to the Fraser, Skeena, and Somass River systems were very low in 2007. (See www.psc.org and commercial fishery notices and escapement reports at www.pac.dfo-mpo.gc.ca for updated information.) Widespread declines in coho and chinook salmon are also evident along the south coast of British Columbia, and pink and chum salmon in the Broughton Archipelago are on a downward trend that the weight of evidence lays at the feet of open net-cage salmon farming.

Current scientific evidence clearly demonstrates that the diversity of salmon and their habitat must be protected in order for the fisheries to remain resilient and sustainable. The critical need to improve the management of salmon fisheries and their habitat is greater than ever. Fortunately, the opportunities are present and the solutions are available.

Executive Summary

This report profiles the current status and trends of 10 examples of salmon stocks in British Columbia that are considered to be in a severe state of decline. (There are many others.) These stocks were selected because they are geographically located within a region where a number of stocks of that species are in decline and the available data provide a reliable index of stocks status. They include four stocks of sockeye (Lakelse, Long, Nimpkish, and Cultus lakes), three of coho (Middle North Thompson, Brunette, and Cowichan rivers), and one each of chinook salmon (Nimpkish River), chum salmon (Viner Sound Creek), and steelhead (Keogh River). For each of the stocks, the available data on escapement, catch, and harvest rates are presented graphically since the early 1980s (or earlier, if data available). We have assessed the impact of human-related activities on fish-spawning and rearing environments in these watersheds, as well as changes in salmon survival at sea, for each stock.

The abundance of these stocks has declined by 70 to 93 per cent since the early 1990s. The decline appears to have been precipitated by poor marine survival. Estimates for South Coast chinook, coho, and steelhead indicator stocks show evidence of a major decline in marine survival rates in the early 1990s. Continued high harvest rates through the mid-1990s resulted in substantial declines for some of these stocks (e.g., Nimpkish River chinook, North Thompson River coho). By the late 1990s, harvest rates had been significantly reduced for most stocks, but abundances remain low due to poor marine survival and degradation of freshwater habitat.

While little can be done to improve marine survival of salmon, it is imperative that harvest rates remain at low levels until there are clear signs of recovery and measures are taken to improve freshwater production through the protection and enhancement of critical spawning and rearing habitat. Specific recommendations for improving freshwater production vary with species and watersheds. Recovery plans have identified specific projects to reverse losses in spawning habitat for sockeye and increase the productivity of freshwater rearing habitat for chinook and coho. In some instances (e.g., Lakelse sockeye, Cultus sockeye, Brunette coho), short-term augmentation of fry or smolt production is necessary to initiate recovery from very low abundance levels. For other stocks (e.g., Smith Inlet sockeye, Cowichan coho, Keogh steelhead), recovery is unlikely until there is significant and sustained improvement in marine survival.

At the end of this report, the David Suzuki Foundation provides a summary of key solutions to help protect and conserve salmon stocks in Canada, based on recommendations taken from this report and other published works by the Foundation.

These solutions include:

- Enforcement of habitat regulations
- Fishing selectively
- Precautionary management
- Legislated protection for endangered stocks
- Implementation of the Wild Salmon Policy

Introduction

This report profiles 10 salmon stocks that are currently in a severe state of decline. The available information on these stocks has been used to describe their current status, identify factors that have contributed to their decline, and determine the actions required for their recovery.

The 10 salmon stocks selected are:

1. **Sockeye – Lakelse Lake (Lower Skeena)**
2. **Sockeye – Long Lake (Smith Inlet)**
3. **Sockeye – Nimpkish (Johnstone Strait)**
4. **Sockeye – Cultus Lake (Lower Fraser)**
5. **Chinook – Nimpkish River (Johnstone Strait)**
6. **Coho – Middle North Thompson River (Interior Fraser)**
7. **Coho – Brunette River (Lower Fraser)**
8. **Coho – Cowichan River (Lower Georgia Strait)**
9. **Chum– Viner Sound Creek (Johnstone Strait)**
10. **Steelhead – Keogh River (Queen Charlotte Sound)**

For each of the above stocks (with the exception of Keogh River steelhead), we compiled the available data on escapement, catch, and harvest rates and prepared summary graphics showing their decline since the early 1980s (or earlier if the appropriate data are available). For Keogh steelhead we show trends in smolt and adult runs and smolt-adult survival. For each of the watersheds where these stocks spawn and rear, we identified the extent of impacts on fish habitat and determined the role that habitat destruction has played in the decline of these stocks. Where possible, we have also assessed the influence of changes in marine survival on the decline and recovery of these stocks.

Methods

The following criteria were used to select the 10 stocks for this review:

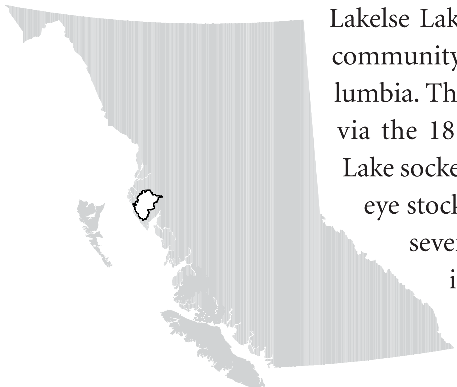
1. **The stock is geographically located within a region where a number of stocks of that species are in decline.**
2. **The escapement data for the selected stock is considered to be sufficiently reliable to be classified as an index stock (i.e., being representative of the status of stocks in a region) by regional fisheries managers or biologists.**
3. **In several cases, these stocks have been identified as stocks in serious decline by fisheries agencies, and recovery plans have been prepared.**
4. **Local groups and government agencies were willing to share information on these stocks.**

One of the first steps in our assessment was to combine the time series of escapement estimates with annual catch or harvest-rate estimates to derive a time series of annual abundance estimates for 1980 through 2006 wherever possible. The quantity and types of information used to derive stock-specific catch or harvest-rate estimates varied substantially for the different stocks and species. In general, harvest rates for the sockeye and chum stocks were derived from run-reconstruction analysis for other stocks of the same species with similar run timing through common fisheries. Chinook and coho harvest rates were derived from coded-wire tag (CWT) data for nearby exploitation-rate indicator stocks. No reliable estimates of marine harvest were available for the Keogh steelhead stock.

All data used to construct the figures in this report are available from the David Suzuki Foundation (www.davidsuzuki.org).

The Stocks

1. LAKELSE LAKE SOCKEYE SALMON



Lakelse Lake is located 20 kilometres south of the community of Terrace in northwestern British Columbia. The lake basin drains into the Skeena River via the 18-kilometre-long Lakelse River. Lakelse Lake sockeye is one of approximately 28 wild sockeye stocks in the Skeena River drainage and, like several of the smaller stocks in the watershed, it is currently depressed compared with historic levels.

Information available on Lakelse Lake sockeye is more extensive than for other lakes in the Skeena drainage due to its accessibility and early interest for enhancement and scientific assessment. In the early 1900s, hatcheries were operated on two of the tributaries that flow into the lake (Coldwater Creek from 1901 to 1920, and Granite Creek from 1920 to 1935). Extensive research was conducted from 1948 through 1965 on basic sockeye life history, freshwater survival, and trends in productivity of this stock (Foerster 1968). From 1962 to 1967, hatcheries, fish fences, and spawning facilities were operated on Williams and Scully creeks, and a weir across the Lakelse River was used to monitor adult escapement and downstream smolt migration. Detail studies of Lakelse Lake were conducted in 1994 and 2003 to assess sockeye production capacity and factors limiting their production (Shortreed 1998, 2003).

Significant human activity in the Lakelse Lake watershed began in the 1950s. These activities, including the cumulative effects of logging, highway construction, creek diversions, and resultant landslides, have likely impacted fish production (Skeena Fisheries Commission 2003). Core samples obtained from the bottom

The Lower Skeena River is an important migration route for sockeye salmon.

of Lakelse Lake in 2002 provided evidence of increased sedimentation associated with development in the watershed (Cummings 2002). The Lakelse Lake Sockeye Recovery Plan (LLSRP), prepared in 2005, identified continued human activity, development, and encroachment in and around Lakelse tributaries used for spawning as high-risk threats affecting sockeye recovery (LLSRP 2005).

Estimates of annual sockeye escapement into Lakelse Lake from 1950 to 2007 are shown in Figure 1. Escapement was generally above 5,000 fish in most years (range 1,000 to 41,000) with peak years of abundance in the 1960s, early 1980s, and mid 1990s, but very low abundance in recent years. Most of the escapement estimates were derived from visual surveys and are considered underestimates of actual escapement, except for the 1960s when both fence counts and calibrated visual estimates were used to derive annual escapement (Foerster 1968). Escapement trends since 1992 suggest that the Lakelse sockeye stock has declined by 92 per cent over the last three cycles. In 2003, an independent assessment of stock status revealed that juvenile sockeye abundance in Lakelse Lake was only nine per cent of the lake's estimated rearing capacity, and represented production from just 750 spawners.

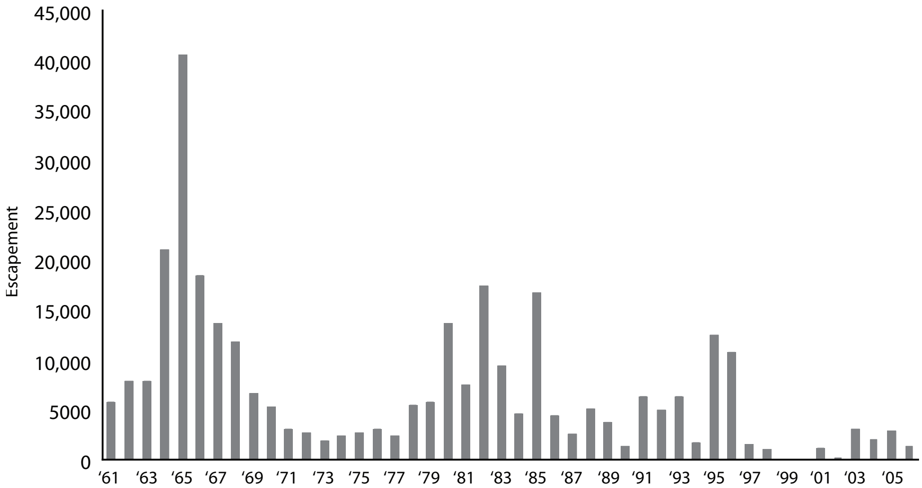


Figure 1. Trends in annual escapement estimates for Lakelse sockeye salmon, 1961-2006.

The fisheries have likely played a role in the decline of Lakelse sockeye, but are not believed to be a major factor because the Lakelse stock migrates through mixed-stock fishing areas before the intensive fisheries that target the enhanced Babine Lake stocks. Exploitation rates estimated for Lakelse sockeye are generally less than 30 per cent (Figure 2) and consistently less than the 43 per cent exploitation rate required for maximum sustained yield of this stock (Cox-Rogers et al. 2004).

Degradation of spawning and incubation habitats is believed to be the major factor affecting sockeye production and recovery in the Lakelse watershed (LLSRP 2005). The quantity and quality of these critical habitats have been impacted by large-scale logging operations, particularly from the mid 1960s to mid 1980s. To

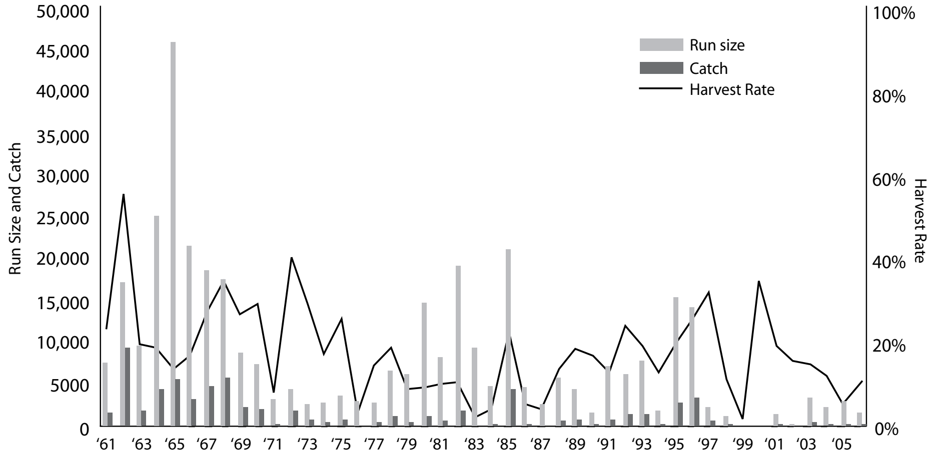


Figure 2. Trends in annual abundance, catch, and harvest-rate estimates for Lakelse sockeye salmon, 1961-2006.

date, 87 per cent of the harvestable timber in the watershed has been logged. Much of this harvesting has occurred in the Williams Creek sub-basin, which typically supports 80 per cent of the sockeye spawners. In addition to logging activities, highway construction and residential developments have also impacted sockeye spawning and rearing habitats.

Consistent with the above observations, the 2005 recovery plan (LLSRP 2005) recommended that immediate action be taken to enhance sockeye fry recruitment to Lakelse Lake, and in the longer term to identify and restore lost critical habitat for sockeye spawning in the lake's tributaries.

Some strategic small-scale enhancement projects that have been selected for immediate action to assist stock recovery are as follows. In August 2006, approximately 100,000 sockeye eggs were collected, fertilized, and transported to Snootlie Hatchery for rearing. The juveniles were released into Lakelse Lake in August 2007, at which time 250,000 eggs were collected for rearing and release into the lake in 2008. Other initiatives currently underway include habitat improvements and feasibility assessments for spawning channels, made possible through the combined efforts of the Lakelse Watershed Society, Kitselas First Nation, Terrace Salmonid Enhancement Society, B.C. Ministry of Environment (MOE), B.C. Timber Sales, and Fisheries and Oceans Canada (DFO). All of these initiatives will need to be continued for a minimum of five years and likely 10 years to make a meaningful contribution to the recovery of this stock.

Recommendations for actions that will assist recovery of this stock include:

- Augmentation of fry production through continued hatchery releases into the lake.
- Restoration of lost critical spawning habitat in tributaries to the lake.
- Supplementation of spawning habitat with a spawning channel.

2. SMITH INLET SOCKEYE SALMON

Sockeye salmon on spawning ground.

Smith Inlet is located immediately to the south of Rivers Inlet, with both inlets located between Calvert Island to the north and Cape Caution to the south on the Central Coast of British Columbia. These inlets have numerous watersheds draining into them, the two most prominent being Owikeno Lake (~96 km^2) draining into Rivers Inlet and Long Lake (~21 km^2) draining into Smith Inlet, with both lakes having an abundance of fish-bearing streams constituting diverse habitats and ecosystems. Populations of all five species of Pacific salmon and steelhead are present in these watersheds, as well as those of several resident species of salmonids (rainbow trout, cutthroat trout, kokanee, and Dolly Varden). Chinook salmon of this area are noted for their large size and are highly sought by anglers because of their trophy status. Earlier in the previous century, these watersheds supported abundant populations of salmon, with the annual sockeye runs of these two inlets combined regularly exceeding two million fish, second in abundance to those of the Fraser River at the time (Rivers and Smith Inlets Salmon Ecosystem Planning Society 2003).

Since 1993, however, the sockeye runs of both these inlets have declined markedly. Although the runs of Rivers Inlet are several fold greater than those of Smith Inlet, the emphasis here will be on Smith Inlet as the escapement data are more reliable owing to the operation of a counting fence on the Docee River since 1972 (Cox-Rogers et al. 2005).

From 1980 to 1993, Smith Inlet sockeye annual escapement ranged from approximately 89,100 to 260,000 fish, and averaged about 194,100 fish. Since then, the escapement has markedly declined, reaching a low 1,430 fish by year 2000, followed by a short-lived rebound to 179,500 fish by 2003, after which it plummeted to an average 16,750 fish annually between 2004 and 2007 (Figure 3). With respect to the rebound in escapement in 2002 and 2003, the returns in 2006 and 2007 were much lower than expected and indicate that Smith Inlet sockeye remain significantly depressed from levels observed in the 1980 to 1993 period.

From 1980 to 1993, total annual sockeye returns to Smith Inlet ranged from approximately 111,000 to 950,000 fish, with an average harvest rate of 50 per cent (Figure 4). With the dramatic decline in the runs, harvest rates were reduced from 55 per cent in 1994 to less than five per cent by 1997, with the inlet closed to commercial fishing since 1998.

The collapse of the sockeye runs in Smith Inlet has been paralleled in Rivers Inlet, with total returns declining to a low 7,000 fish in 1999, with a rebound to approximately 100,000 fish in 2002, which, like in Smith Inlet, has not been sustained. Recovery of both these Central Coast stocks is expected to take several years (Riddell 2004).

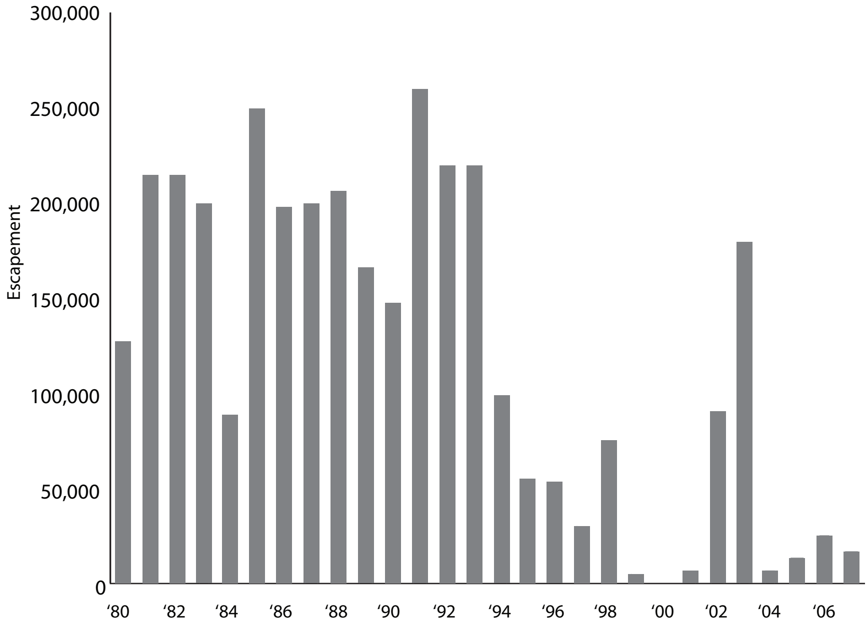


Figure 3. Trends in annual escapement estimates for Smith Inlet sockeye salmon, 1980-2007.

Long Lake was fertilized in most years between 1977 and 1997 (Shortreed et al. 2001) to increase the lake's primary productivity and sockeye smolt size and survival at sea. Average adult return rates increased in the years following fertilization, but that may not be attributable solely to the benefits of fertilization, as sockeye stocks in Owikeno Lake with no fertilization also had high return rates during the same period. Since 1997, Long Lake has not been fertilized as there were indications that sockeye fry survival had improved under low population levels (Hyatt et al. 2000) and fertilization was therefore not warranted (Shortreed et al. 2001). In an effort to prevent further decline and possible extirpation of the stocks, annual releases of marked hatchery fry of 50,000 and 200,000 fish have been made in Canoe and Smokehouse creeks from brood years between 2000 and 2004; the contribution of these releases to adult returns is not yet available.

Reasons for the decline of the sockeye runs in Smith Inlet, as well as those of Rivers Inlet, are not well understood. Only a few salmon populations and their freshwater habitats have been regularly monitored in this area (e.g., enumeration fence on the Docee River, tributary to Long Lake), and the marine environment has not been monitored until very recently. The decline of these stocks cannot be adequately explained by deterioration of the freshwater environments, as most of these are not extensively logged or heavily impacted by human developments and water consumption. Information on smolt abundance and adult returns indicates there was a significant decline in sockeye marine survival during the 1990s (Hyatt et al. 2000). Smith and Rivers inlet sockeye are likely vulnerable to changes in the marine environment given that the out-migrating smolts from these watersheds are among the smallest for any sockeye population. Therefore, it is unlikely that

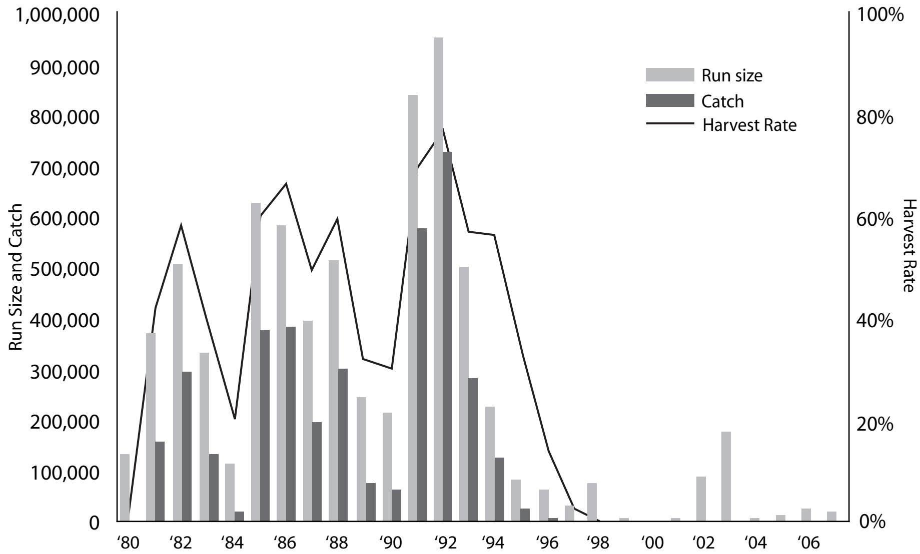


Figure 4. Trends in annual abundance, catch, and harvest-rate estimates for Smith Inlet sockeye salmon, 1980-2007.

these stocks will recover until there is a significant and sustained improvement in marine survival (Rutherford and Wood 2000).

Given the currently low escapement levels and likely controlling influence of marine survival, recommended actions for recovery of Smith and Rivers inlet sockeye stocks include:

- Continue with annual releases of 50,000 to 200,000 fry into Canoe and Smokehouse creeks to augment natural production.
- Maintain the current closure of Areas 9 and 10 to commercial fishing until the stocks sufficiently recover.
- Re-examine the potential benefits of fertilization when the abundance of these stocks rises to a level that fresh water might be limiting smolt production.

3. NIMPKISH RIVER SOCKEYE SALMON

Adult sockeye ready to spawn.

The Nimpkish River, the largest drainage on Vancouver Island, drains an area of approximately 2,226 square kilometres of the northern portion of the island. Nimpkish Lake, by far the largest lake (~38 km^2) in the watershed, is located near the mouth of the river. The lake is an important nursery area for sockeye fry resulting from lakeshore spawning, as well as from sockeye spawning in the Nimpkish River mainstem and lower Woss and Sebalhall rivers. The Woss River system is one of the most productive in the Nimpkish watershed, contributing 30 to 50 per cent of the total Nimpkish sockeye spawning population.

Historically, the Nimpkish watershed was a major producer of all five species of Pacific salmon and steelhead. From 1945 to 1975, Nimpkish sockeye returns averaged about 100,000 fish annually. In the following decade, the runs declined sharply, followed by considerable instability, with very low returns in some years and strong returns in others (e.g., 1987, 1988, 1992, 1997, and 2002) as shown in Figure 5. In all years, Nimpkish sockeye returns represent more than 85 per cent of the total observed sockeye escapement to Area 12. Estimated annual run size from 1980 to 2004 has varied from 5,800 to 238,000 fish, with the harvest rate dropping from an average 25 per cent (pre-1987 era) to eight per cent, with zero harvest in some years (Figure 6). Due to the unpredictable nature of the runs, the years with high returns were in most instances virtually unexploited.

Given the relatively minor influence of fisheries on this stock, the most likely explanation for the observed variability in escapement numbers is the large variation in year-class strength, variation in the age at return, and marine survival. Currently, low marine survival is likely the most important factor limiting the recovery of this stock. Predation by sea-run Dolly Varden on juvenile sockeye and chum in the estuary has been observed to be considerable (Mike Berry, Alby Systems Ltd., Alert Bay, pers. comm.) and may be an important factor contributing to mortality of sockeye smolts during their migration from fresh water to the marine environment. Moreover, climate change may be adversely affecting the salmon's ocean food resources such as euphausids.

Forestry, beginning in the 1880s, is the major industry in this watershed and attained industrial proportions by the 1920s, when railroads were built to haul logs to tidewater (Weinstein 1991). Log-handling activities occurred on Nimpkish Lake in the past, with logs boomed into the lake and towed to the north end for loading onto the rail system. Other impacts, but considerably less significant than forestry, include the Island Highway along the Nimpkish River to Woss; the BC

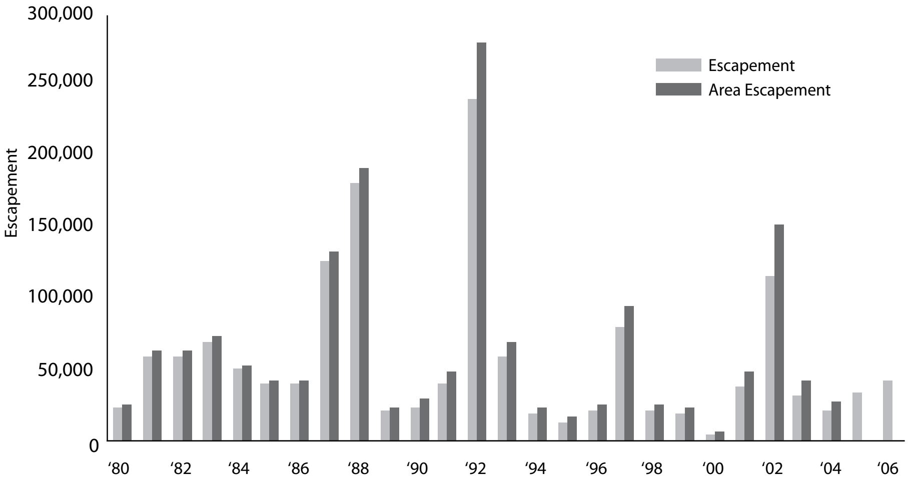


Figure 5. Trends in annual escapement estimates for Nimpkish sockeye salmon, 1980-2006. Comparable escapement estimates are shown for Statistical Area 12 up to 2004.

Hydro transmission line that crosses the river at several sites; the Village of Woss; and two sawmills (one near Woss, the other near Croman Lake). Also, the impact of predation by seals, sea lions, birds, and predatory fish on smolts in the Nimpkish estuary may be considerable and requires investigation by DFO.

Sediment inputs from various tributaries have caused significant aggradations in the upper Nimpkish River, which has led to considerable channel-widening, bar formations, and braiding (NRMB 2003). Similarly, the Woss River has been significantly impacted by sediment and large woody debris inputs to the lower reaches, resulting in considerable loss of spawning habitat for sockeye. Recently, various in-stream restoration works were undertaken to assist recovery of the sockeye population (NRMB 2003). In addition, two recently constructed side channels –

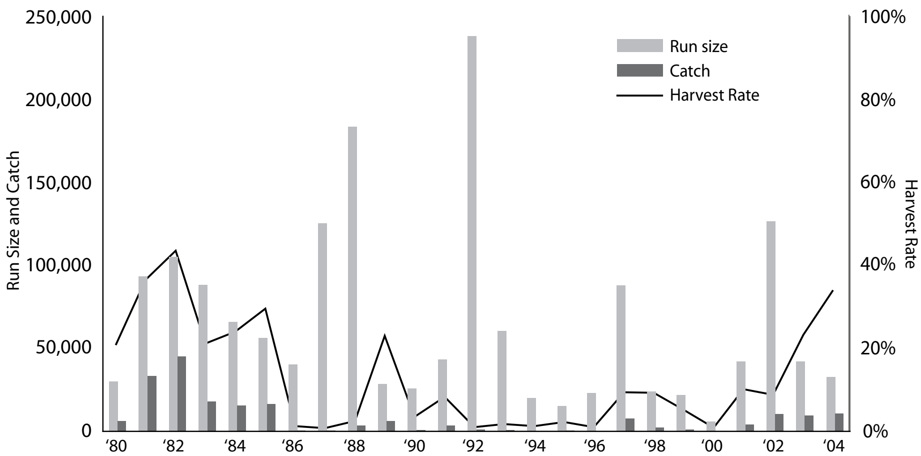


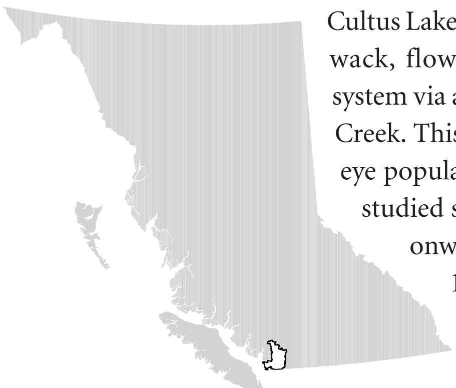
Figure 6. Trends in annual abundance, catch, and harvest-rate estimates for Nimpkish sockeye, 1980-2004. Harvest rate estimates are not available for 2005 and 2006.

one in the Nimpkish/Woss confluence area and the other off the lower Sebalhall River – provide some additional spawning habitat for sockeye. Also, fertilization and fry out-planting programs are ongoing in Woss and Vernon lakes to increase growth of sockeye smolts and survival in the ocean.

The Nimpkish Resource Management Board (2003) concluded that Nimpkish sockeye runs appear to be most limited by: 1) reduced numbers of spawners in Woss, Vernon, and Nimpkish lakes, all of which have the capacity to produce large numbers of smolts; 2) serious decline or extirpation of stocks in several lakes and streams; and 3) extreme variability in year-class strength in the last two decades. While the rate of recovery for Nimpkish sockeye will largely be determined by marine survival rates, the following actions are recommended to protect this stock through periods of low marine survival and maximize the potential for recovery:

- Maintain harvest rates at low levels while the runs are recovering, particularly for year classes that have been repeatedly low for several generations.
- Continue with in-stream habitat improvements, side channels to lake tributaries for sockeye spawning, and lake fertilization programs to enhance smolt production and returns to help offset the currently low marine survival of salmon.

4. CULTUS LAKE SOCKEYE SALMON



Cultus Lake, located between Abbotsford and Chilliwack, flows directly into the Vedder-Chilliwack system via a short and stable outlet stream, Sweltzer Creek. This small lake (~6.3 km^2) supports a sockeye population that is among the most intensively studied stocks in B.C., extending from the 1920s onward (e.g., Foerster 1929a, 1929b, 1929c, 1934, 1936; Ricker 1935, 1937, 1938, 1952; Howard 1948; Cooper 1952; Stock Assessment and Fisheries Management Work Group [SAFMWG] 2002). These studies provide a valuable long-term database on population statistics and other parameters, including the effects of predator removal in the lake on sockeye smolt size and survival. Cultus Lake was chosen for biological study because of its manageable size, year-round road access, ice-free conditions during winter, and stable outlet stream that could be completely fenced for smolt and adult salmon enumeration. The fence, located approximately 200 metres downstream from the lake, has been operated every year since 1925, usually from September through December up until 1996; however, since then, the fence has been installed progressively earlier to accommodate the earlier migration of this stock (SAFMWG 2002).

A sockeye is sampled in the Lower Fraser River.

Biological information is obtained from carcasses recovered at the fence and on the spawning grounds. Historically, weekly spawning-ground surveys were conducted on foot along Lindell Beach (lake foreshore) from mid-October to mid-December. The extent and frequency of these surveys declined during the 1980s and early 1990s, with most biological samples obtained at the fence. However, since 1999, weekly ground surveys have been reinstated over an expanded period (early September to mid-December), augmented by boat surveys to improve the accuracy of the spawning counts (SAFMWG 2002).

The Chilliwack River system supports two genetically distinct sockeye stocks: an early summer run that spawns in Chilliwack Lake and upper Chilliwack River, and a late run that spawns in Cultus Lake. Late-run sockeye mature predominantly in their fourth year and tend to show a four-year abundance cycle: dominant, sub-dominant, and two relatively weak year classes (SAFMWG 2002). Historically, Cultus sockeye migrated through coastal waters in August with summer-run stocks but resided in lower Georgia Strait for three to six weeks before migrating upriver. Prior to 1995, Cultus sockeye adults migrated through the lower Fraser River in September and October and into Cultus Lake from late September to early December. Since then, the delay has become progressively shorter, with spawners arriving at Cultus Lake as early as mid-August. Their earlier arrival has resulted in high mortality due to heavy infestations of *Parvicapsula minibicornis*, a parasite that attacks the kidneys and gills (St-Hilaire et al. 2001). Although the parasite infects most Fraser sockeye as they enter the river, its impacts are greatest on early migrating late-run stocks that spend more than five weeks in fresh water prior to spawning.

Spawning in Cultus Lake occurs on gravel beaches around the lake. Fry emerge from the gravel between April and July and rear in the lake for up to two years, although most migrate to the sea as one-year-old smolts from late March through June. Fraser sockeye smolts (including those from Cultus Lake) move quickly through the estuary into the Strait of Georgia (Healy 1980), through Johnstone Strait by July, and then head northwest along the coast and offshore into the Gulf of Alaska where they rear with other sockeye stocks for about two years (SAFMWG 2002). Returning Fraser sockeye (mostly four-year-olds) from the northwest Pacific Ocean enter the Strait of Georgia in August through either Johnstone or Juan de Fuca straits, and are harvested by mixed-stock fisheries along the coast of B.C. and in the lower Fraser River.

Trends in Cultus sockeye escapement can be broadly categorized into four time periods (Figure 7): generally high escapement in the dominant year class (but low in others) during large-scale hatchery operations in the 1920s and 1930s; high escapement in 1939 and 1940 in response to major predator removal in the lake; strong but variable escapement from the early 1940s to late 1960s; and declining escapement from 1969 to the present, although less pronounced for the dominant year class. From 1997 to 2006, average escapement for all year classes combined (2,752 fish) was the lowest ever recorded for a 10-year period. The combination of declining escapement and high pre-spawn mortality resulted in the stock being listed as endangered in 2002 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

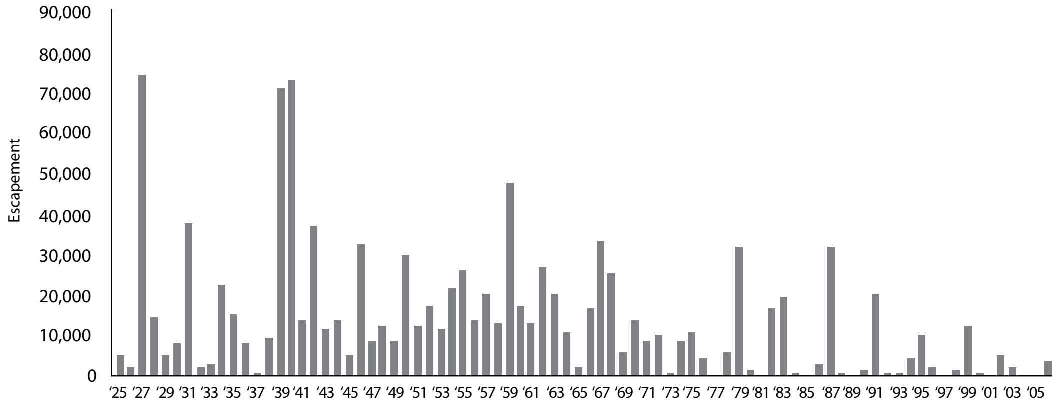


Figure 7. Trends in annual escapement estimates for Cultus River sockeye salmon, 1925-2006.

The estimated total annual catch of Cultus sockeye in all fisheries combined from 1952 to 2006 has averaged 47,195 fish, with a peak 355,017 fish in 1959 and a low 27 fish in 2004 (Figure 8). Up to the early 1990s, harvest rates averaged about 75 per cent, but since then were reduced to about 20 per cent in most years. The catch in Fraser River First Nations and sport fisheries has been minor, representing about two per cent of the total harvest from 1974 to 2001.

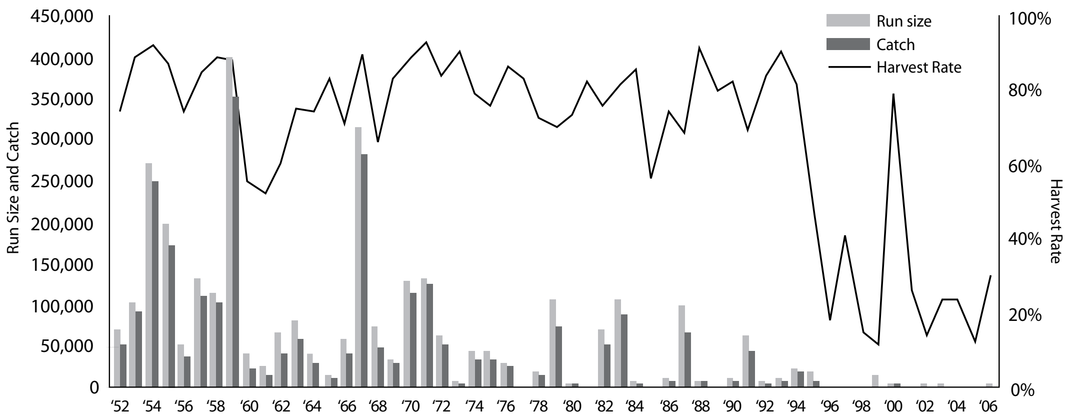


Figure 8. Trends in estimated annual abundance, catch, and harvest rate for Cultus Lake sockeye salmon, 1952-2006.

Over the years, Cultus sockeye have been used for a variety of enhancement and experimental projects. From 1918 to 1924, an annual average of 4.7 million eggs was taken by the hatchery for subsequent planting of eyed eggs, releases of free-swimming fry, and transplants to other rivers. Between 1926 and 1934, a major egg-to-smolt survival study was conducted on the lake, and then discontinued as no difference in survival was detected among the experimental groups. In recent years, the hatchery has focused on rearing captive brood stock from wild smolts for the purpose of producing fry and smolts for release into the lake to assist stock recovery.

There is evidence that Eurasian milfoil (an invasive exotic), stream channelization, and lake-foreshore development have impacted prime spawning sites, but these are not considered the main causes of the sockeye decline. The main causes for the decline listed by COSEWIC (2003) include:

- Overexploitation of the stock up to mid 1990s, which increased its susceptibility to natural mortality causes.
- Poor marine survival in the early 1990s.
- Increased pre-spawning mortality since the mid-1990s due to their earlier migration into fresh water and increased infestation of *Parvicapsula*.

The general consensus of fisheries experts is that if pre-spawning mortality of Cultus sockeye remains high, the stock will continue to decline even if exploitation rates are negligible. Because of its extremely low level of abundance, this stock is more susceptible to adverse environmental conditions that result in poor marine survival or high pre-spawn mortality. To assist stock recovery, it is recommended that future effort focus on the following:

- Determine the cause of earlier migration of late-run sockeye stocks.
- Continue with brood-stock development from wild smolts.
- Enhance freshwater survival through lake fertilization, predator control, and improvements to critical spawning and rearing habitat in Cultus Lake.

Chinook salmon are a critical food source for resident killer whales.

5. NIMPKISH RIVER CHINOOK SALMON

The Nimpkish watershed is located approximately 140 kilometres north of Campbell River on the east coast of Vancouver Island. Duration of freshwater residency of Nimpkish chinook ranges from three months to one year. Fish that spend only three months in fresh water tend to spend considerable time in the estuary, where predation by seals and birds is high. Those that stay in fresh water for longer are of a larger size when they go to sea, and tend to survive better to adulthood. Nimpkish chinook return to spawn mostly at four years of age (~70 per cent of the population), but also at ages three (<10 per cent) and five (~20 per cent) and infrequently at six years. Historically, these chinook were renowned for their large size (up to 30 kilograms), but in recent times they are substantially smaller (Nimpkish Resource Management Board [NRMB] 2003). Spawning has been recorded mainly in the Woss River and sporadically in other areas, including lower Atluck Creek and Sebalhall and Nimpkish rivers, particularly near the Woss River confluence and below Nimpkish Lake.

In the 1920s and 1930s, harvest of Nimpkish salmon supported a cannery located at Alert Bay. During this period, local anglers and naturalists, including Roderick Haig-Brown and Billy Proctor, estimated the average annual chinook returns at 25,000 to 30,000 and as high as 100,000 in peak years. In more recent years, helicopter and snorkel surveys combined with streamside counts have improved the accuracy of escapement estimates, but the numbers observed are less than five per cent of historic levels. The 1994 escapement estimate of only 229 chinook was the historic low point for the Nimpkish River (Figure 9). Escapement estimates for 2005 did not exceed 500 fish, although spawner estimation was hampered by bad weather conditions (Pieter Van Will, DFO, Stock Assessment Biologist, Port Hardy, pers. comm.).

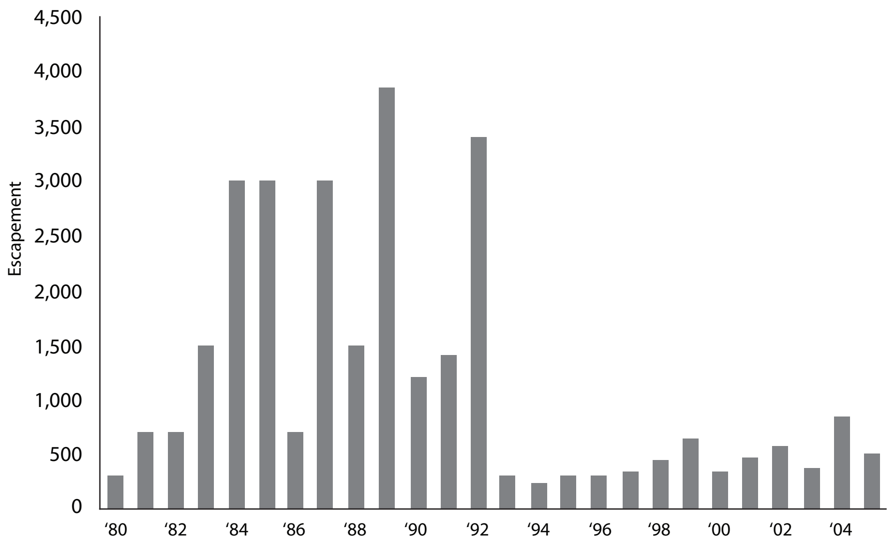


Figure 9. Trends in annual escapement estimates for Nimpkish River chinook salmon, 1980-2005.

Estimates of total returns from 1980 to 2005 show a substantial change in abundance between the 1983 to 1992 period and the post-1992 returns (Figure 10). Data from CWT returns for Quinsam chinook suggest that harvest rates on this mid-east coast Vancouver Island stock remained roughly in the 35 to 55 per cent range for five years after the marked decline in returns in 1993. Canadian harvest rates dropped to less than 20 per cent in 1998. Restrictions to Johnstone Strait net fisheries and B.C. troll fisheries have kept Canadian harvest rates at or below the 20 per cent level through 2005. However, the total harvest rate for Quinsam and possibly other mid-east coast Vancouver Island chinook stocks has increased substantially since 2001 as a direct result of the increased interceptions in Alaskan fisheries. Smolt to adult survival estimates for Quinsam chinook over the last two decades (Fisheries and Oceans Canada) suggest that low marine survival is another important factor affecting the recovery of Nimpkish chinook. Since the mid 1980s, marine survival of Quinsam chinook has generally been less than two per cent, whereas previously it was as high as eight per cent in some years.

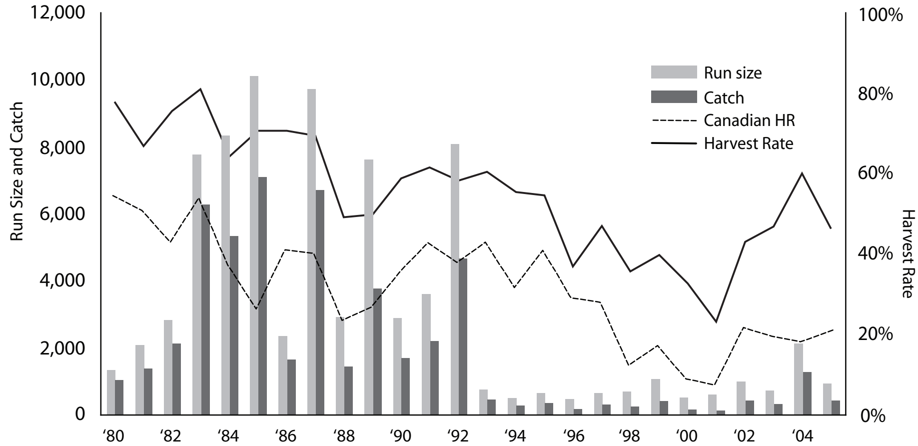


Figure 10. Trends in annual abundance, catch, and harvest-rate estimates for Nimpkish River chinook salmon, 1980-2006.

Overfishing has been identified as the primary reason for the major decline in spawners and total returns for Nimpkish chinook in 1993 (NRMB 2003). Harvest rates between 1990 and 1996 were similar to those in the 1980s, but marine survival dropped significantly in the early 1990s for most chinook and coho stocks on the eastern side of Vancouver Island. Stocks like Nimpkish chinook that could support 40 to 60 per cent harvest rates up to the mid-1980s could not support this level of exploitation when marine survival rates dropped to less than two per cent. Most of the watershed has been impacted by logging and road construction, and the effects on chinook spawning and rearing habitats have been implicated in the decline of these stocks (NRMB 2003).

Some fertilization has occurred in Woss and Vernon lakes in collaboration with the Department of Fisheries and Oceans and the B.C. Ministry of Environment (MOE). Also, some stream-based fertilization has been undertaken by MOE in recent years throughout the watershed to improve primary production. The effect of these enhancement activities on increasing smolt size and marine survival of chinook is not known at this stage.

In implementing actions for recovery of this stock there is a need to develop a better stock-assessment framework to work with. Under current coverage, escapement is likely underestimated, but even so, abundance is unquestionably low. Since 1992, a substantial proportion of the hatchery releases have been coded-wire-tagged to obtain better information on marine distribution and interception in the fisheries. To date, most of the catch data are from the Central Coast recreational fishery, which is heavily weighted to local waters (P. Van Will, pers. comm.).

Remedial measures to improve habitat for spawners and juveniles are difficult to implement for chinook as they use mainstem areas in large rivers. Habitat improvements would require in-stream works in the Woss, Sebalhall, and Nimpkish rivers involving major engineering and logistical problems. In light of these problems, the recommended actions to promote the recovery of Nimpkish chinook include:

- Local area and time closures for commercial and recreational fisheries to reduce the bycatch of Nimpkish chinook in fisheries that target other stocks.
- The addition of fertilizer (liquid or pellets) to increase the productivity of the rearing area for juvenile chinook to increase smolt size and improve their survival in the ocean.

A significant limitation to implementing the first option is that migration routes and timing of Nimpkish chinook may not be well enough known to implement effective closures. Some information on river entry is available from snorkelling surveys (July-August), and indications from recoveries in Area 12 sportfishing are that the stock is more locally distributed and intercepted in Knight Inlet fishing and possibly up into Kingcome and Wakeman inlets (P. Van Will, pers. comm.).

6. MIDDLE NORTH THOMPSON RIVER COHO SALMON

The Thompson River is a major tributary of the Fraser River watershed. The mid North Thompson comprises that portion of the North Thompson mainstem and its tributaries from the mouth of the Clearwater River to Little Hells Gate and beyond (since blasting in 2000, these rapids no longer restrict coho passage during low flows). The area includes several productive tributaries and groundwater side channels used by coho salmon, with Reg Christie, Wire Cache, Finn and Lyon creeks, and Raft River being important spawning areas (Interior Fraser Coho Recovery Team [IFCRT] 2006). During years of low flows, spawning in the mid North Thompson watershed is largely limited to specific areas in the mainstem of the river, whereas in years of higher flows both tributary and side channel habitats are used as well. Spawning has been recorded in the Clearwater River up to the confluence with the Mahood River.

The Lower Thompson River is an area of difficult migration for adult salmon.

Estimates of coho annual escapement for the mid North Thompson for the period 1980 to 2006 have varied considerably between years (Figure 11), although since 1992 (with the exception of 2001) there is clear evidence that spawner abundance has declined markedly. Prior to the decline, the average annual escapement amounted to approximately 9,100 fish, whereas since the decline it dropped to approximately 3,700 fish, with a low of 430 spawners returning in 2006.

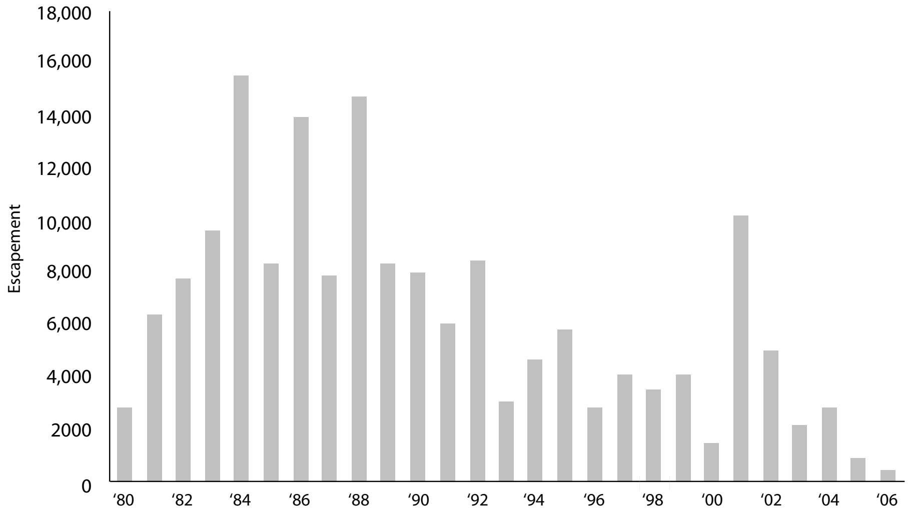


Figure 11. Trends in annual escapement estimates for Middle North Thompson coho salmon, 1980-2006.

From 1980 to 1992, the estimated annual runs of mid North Thompson coho averaged about 29,850 fish, with harvest rates ranging from 60 to 80 per cent (Figure 12). However, with the decline in marine survival in the early 1990s and continuing high harvest rates (40 to 80 per cent) for some five years after, the runs could not sustain such fishing pressure and collapsed. In spite of harvest rates being less than 10 per cent since 1998, with the exception of a moderate rebound in 2001, the runs show no sign of recovery, with fewer than 500 fish in 2006.

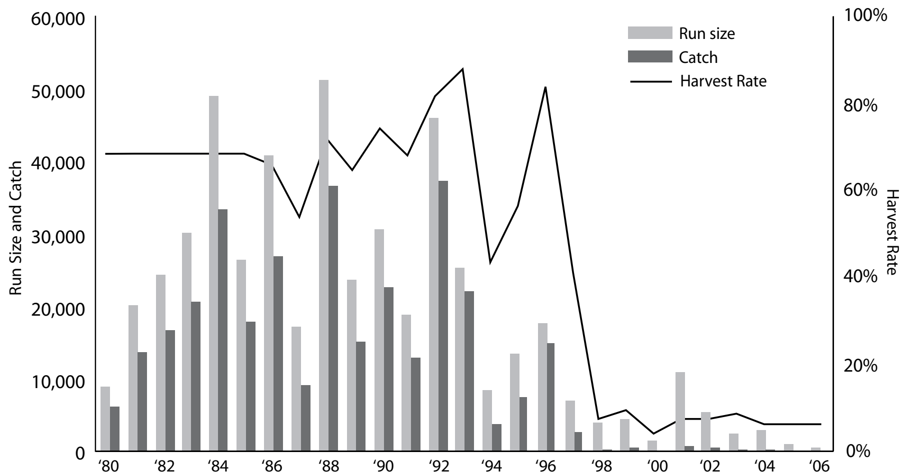


Figure 12. Trends in annual abundance, catch, and harvest-rate estimates for Middle North Thompson River coho salmon, 1980-2006.

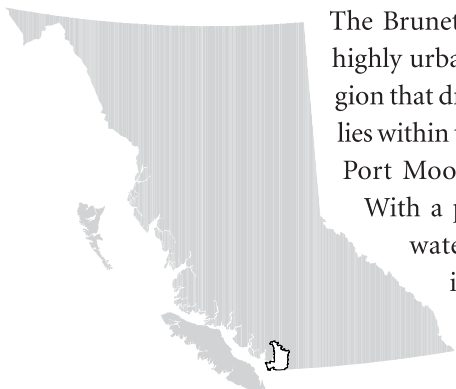
Interior Fraser coho stocks have been COSEWIC listed since 2002, but are not listed under the Species at Risk Act (SARA). The COSEWIC designation prompted the need for immediate recovery goals to be established by the Interior Fraser Coho

Recovery Team (DFO 2005). The major factors contributing to the decline of these stocks appear to be excessive exploitation rates and habitat alteration, disruption and destruction from various human activities (logging, agriculture, hatchery influences, urban/rural developments, mining), and effects of climate change (IFCRT 2006). The IFCRT classified 60 per cent of the coho streams in the middle North Thompson as highly impacted by either logging or linear development. While there is no doubt that the freshwater impacts are considerable, the continuing low marine survival rates are no doubt impeding recovery of these coho stocks.

Recommended actions that will assist the recovery of mid-North Thompson coho include:

- Maintain harvest rates at low levels.
- Maintain summer flows above critically low levels to provide sufficient suitable rearing habitat for coho fry.
- Restore and protect important spawning and rearing habitats (including winter refugia) in tributaries and side channels.

7. BRUNETTE RIVER COHO SALMON



This heavily silted channel of the Lower Brunette River is poor habitat for salmon and their prey.

The Brunette watershed (~73 km^2) is located in a highly urbanized area of the Greater Vancouver region that drains into the Fraser River. The watershed lies within the municipalities of Vancouver, Burnaby, Port Moody, Coquitlam, and New Westminster. With a population of over 175,000 people, the watershed has been extensively altered by industrial and residential developments, road networks, and utility corridors. Currently, just over 20 per cent of the area remains as parks, protected waters and wetlands, and undeveloped green space.

The Brunette is a lake-fed system with Burnaby Lake and its tributaries contributing to most of the river's flow. Tributaries of importance for coho spawning in the past included Still, Eagle, and Stoney creeks and others, whereas currently only Eagle and Robert Burnaby creeks are the main spawning areas. Historically, the Brunette was a slow-flowing river with extensive meanders providing an abundance of suitable habitat for juvenile coho. However, in the 1920s, the oxbows were cut off to straighten the river's course to prevent flooding during high flows. The removal of the oxbows resulted in increased gradient and reduced the quality and quantity of coho rearing habitat. To reduce the flows, dams were installed at various locations, including fishways, to allow for fish passage.

According to maps and materials by the Heritage Advisory Committee and Environment and Waste Management Committee of the City of Burnaby (1993), the number of native campsites as well as some petroglyphs discovered on the shores of the Fraser River, Burrard Inlet, and Deer Lake suggest that the area was extensively used by local aboriginal people such as the Squamish, Musqueam, and Kwantlen for hunting and fishing before the arrival of European settlers. William Holmes was the earliest known European immigrant to settle on the banks of the Brunette River in 1860, now known as the North Road. According to his daughter, Charlotte, local Native people gathered at their farm each season to catch and dry their winter supplies of salmon. She remembers the salmon runs being so large on the Brunette River that the fish were virtually crowding each other out of preferred areas.

Historically, coho, chum, and pink salmon, and sea-run cutthroat and steelhead were present in the Brunette watershed, with spawning occurring mainly in tributaries to the lake. By the mid 1950s, the coho run was virtually extirpated due mainly to industrial developments, and oil and gas spills from trucks and other equipment into Still Creek, the primary spawning area for coho salmon (Elmer Rudolph, Sapperton Fish and Game Club, pers. comm.). Also, in the 1970s, sediment surveys conducted by graduate students of the University of British Columbia revealed the presence of heavy metals in the upper part of Still Creek.

Since the early 1980s, coho have made a minor comeback in the Brunette, with escapement averaging 357 fish annually from 1987 to 1996, with a peak of about 800 fish in 1992; however, from 1998 to 2006, escapement has been consistently low, ranging from 18 to 98 fish (Figure 13).

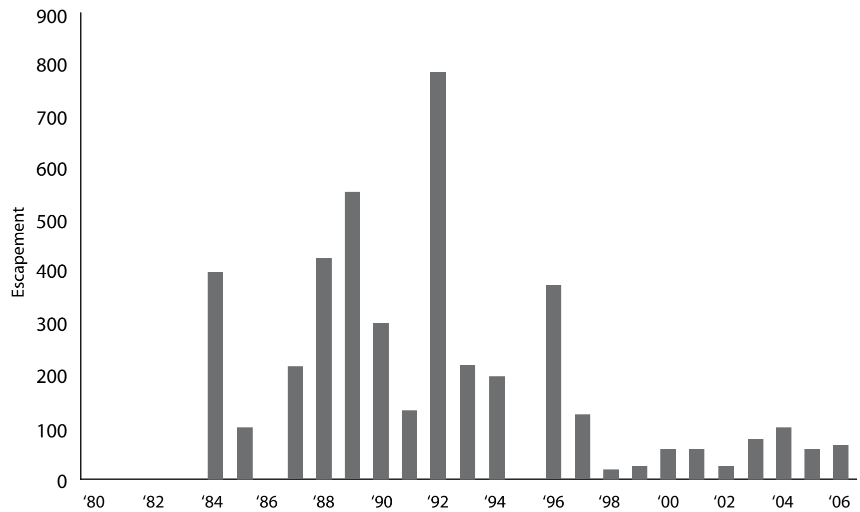


Figure 13. Trends in annual escapement estimates for Brunette River coho salmon, 1980-2006.

The estimated average annual run from 1984 to 1996 has amounted to 1,062 fish, with the harvest rate ranging from 60 to 80 per cent (Figure 14). Since 1998, the runs have been exceedingly low, averaging about 60 fish annually, in spite of very low harvest rates (<10 per cent). Predation by largemouth bass in the lower river may be a factor affecting coho abundance. Largemouth bass prefer warmer water and have been observed migrating from the Fraser River into the Brunette River (where temperatures are warmer during summer), but not past the first fishway located about one kilometre upstream of North Road. When river temperatures cool sufficiently in the Brunette, the bass tend to return to the Fraser River (Elmer Rudolph, pers. comm.).

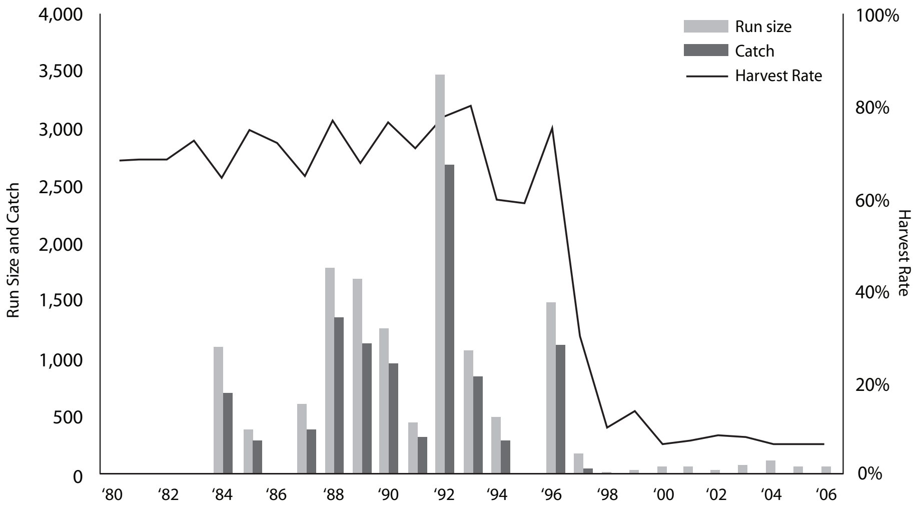


Figure 14. Trends in annual abundance, catch, and harvest-rate estimates for Brunette River coho salmon, 1980-2006.

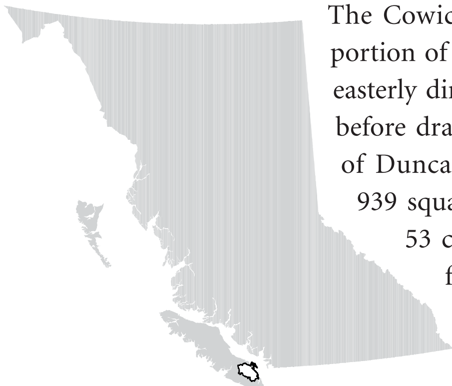
Various works have been completed by the Sapperton Fish and Game Club (SFGC) and government agencies to improve water quality and habitat for salmonids in the Brunette River. In 1992, a new fishway was installed at the Caribou Dam to allow spawners access to tributaries to Burnaby and Deer lakes. A salmon hatchery with capacity to produce 40,000 coho fry has been operated since 1997, although recently only about 10,000 fry have been released each spring into tributaries downstream of Burnaby Lake using broodstock from the Brunette River; however, returns from these releases have been low. A series of Newberry weirs was installed in the lower mainstem of the Brunette in the late 1990s to improve dissolved oxygen levels during summer. In addition, various habitat improvements have been made in strategic locations, including installation of tree stumps, logs, and boulder complexes, construction of riffle habitat, and placement of gravel in specific areas for salmonid spawning.

Recommended actions to assist with the recovery of Brunette coho include the following:

- Remove large logs and debris that have accumulated at the mouth of the Brunette River to improve flushing/cleansing of the river during high flows and access for salmonids.
- Create additional off-channel rearing habitat to the Brunette mainstem.
- Improve dissolved oxygen levels in the Brunette River by aerating the outflow from Burnaby Lake during summer months.

Channel realignment and bank armouring at Stoltz Bluff in the Cowichan River.

8. COWICHAN RIVER COHO SALMON



The Cowichan River is located on the southeast portion of Vancouver Island and flows in a south-easterly direction for approximately 47 kilometres before draining into Cowichan Bay near the City of Duncan. With a watershed of approximately 939 square kilometres and a mean discharge of 53 cubic metres, the Cowichan River ranks fourth in size on Vancouver Island after the Nimpkish, Campbell, and Stamp-Somass rivers (Cowichan Recovery Plan 2005); the Cowichan is recognized as one of the seven most important coho producers in the province (Aro and Shepard 1967).

The Cowichan River supports anadromous populations of chinook, coho, and chum salmon, winter-run steelhead, sea-run cutthroat trout, and resident populations of kokanee (in the lake), rainbow trout, cutthroat trout, and Dolly Varden. Sockeye and pink salmon and white sturgeon (*Acipenser transmontanus*) have been reported, but are rare. Brown trout (*Salmo trutta*) were introduced in the 1930s and are currently found in the system.

There are three partial obstructions to fish passage on the Cowichan River mainstem. In 1957, a low-level (one-metre-high) flow-control weir was constructed at the outlet of Cowichan Lake. The weir is managed from about mid-April to mid-October to ensure an adequate water supply for a pulp mill in Crofton and to provide sufficient flows for spawning and rearing fish (MEP 1986). A fishway in the weir allows fish passage between the river and the lake. Another partial obstruction is Skutz Falls (a 5.5-metre vertical drop over a distance of 90 metres), located 20.5 kilometres below Cowichan Lake. In 1955, a vertical-slot fishway was constructed at Skutz Falls to facilitate passage of salmon at all water levels (Lill et al. 1975). The third partial obstruction is Marie Canyon (a three-metre vertical drop in 30 metres) located 15 kilometres below Cowichan Lake.

Maturing adult coho salmon are known to stage in Cowichan Bay between late August and early November. Upstream migration typically begins during the first major increase in river flow around mid-October and continues through December (Neave 1949; Lill et al. 1975; CETF 1980a). Spawning begins in late September to early October, peaks in November, and continues through January (Lill et al. 1975; CETF 1980a). Coho spawn heavily in the Cowichan River mainstem, particularly above Skutz Falls, but also utilize tributaries to the river and Cowichan Lake (Neave 1949; Lister et al. 1971). Spawning is also known to occur in the lower river and in channels and ditches near the estuary (CETF 1980a). Currently, two hatcheries operate on the Cowichan River, one located five kilometres upstream of the Cowichan River estuary, managed by Cowichan Tribes, and the other situated approximately one kilometre downstream of the Island Highway Bridge, which is used mainly for steelhead and trout culture, currently amounting to about 50,000 steelhead annually for release into the Cowichan River. Between 1977 and 2003, a total of 2.5 million coho fry have been released into the river below the weir at the outlet of Cowichan Lake, with a peak of 335,864 fish in 1988.

From 1937 to 2003, escapement estimates for Cowichan River coho salmon averaged 32,361 fish (Cowichan Recovery Plan 2005). Escapement was estimated to reach 75,000 fish on several occasions from the mid-1950s to the late 1970s, while the lowest escapements on record occurred in 1996 and 2006 (Figure 15). From 1997 to 2004, regulatory changes enacted to conserve threatened coho stocks improved escapement for Cowichan coho and other Strait of Georgia stocks. However, the recent steady decline in escapement from 16,100 in 2003 to 2,500 in 2006 has renewed concerns for this important coho stock.

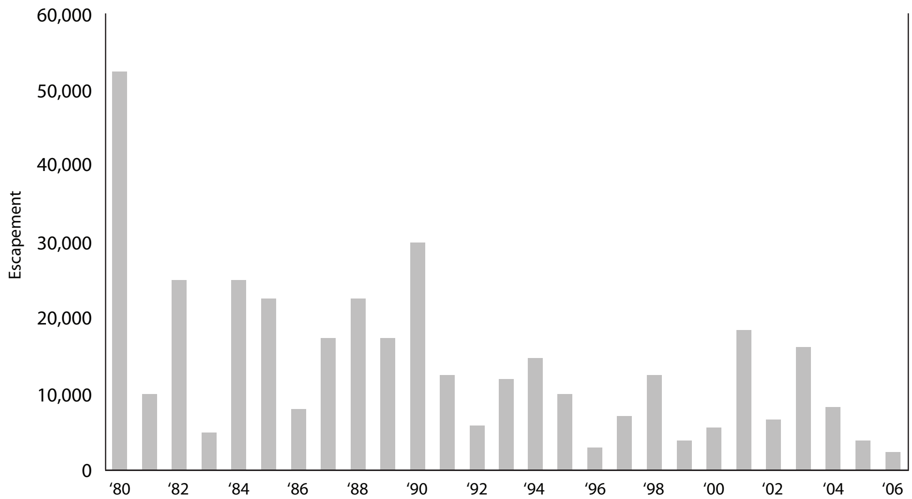


Figure 15. Trends in annual escapement estimates for Cowichan River coho salmon, 1980-2006.

Estimates of total returns from 1980 to 2006 show a substantial change in abundance between the 1980 to 1990 period and post-1990 era, with the runs declining from an average of 87,760 to 17,300 fish, with the greatest drop in abundance occurring between 1991 and 1995 (Figure 16). Harvest rates were maintained at 60 to 70 per cent up to the mid 1990s, and probably well above what the stock could sustain when marine survival dropped in the early 1990s. Since 1998, the harvest has been maintained at less than 10 per cent, with some minor but inconsistent rebound of the runs.

The distribution of Cowichan coho at sea is not well known. Wild-smolt tagging has not been conducted routinely each year. Moreover, coho released from the hatchery during 1982 to 2002 (production and salvaged fry) were not coded-wire-tagged prior to release, and commercial catches were not subjected to bio-sampling and DNA analyses. Information from minimal tagging of wild smolts in the 1970s suggests that, unlike other Georgia Strait stocks, Cowichan coho tend to remain on the west coast of Vancouver Island during their second year at sea (Argue et al. 1986).

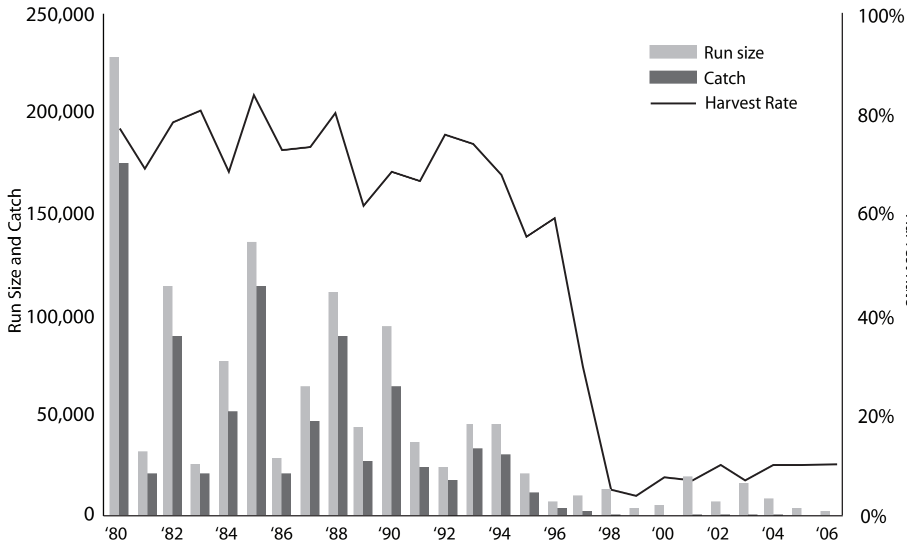


Figure 16. Trends in annual abundance, catch, and harvest-rate estimates for Cowichan River coho salmon, 1980-2006.

Cowichan salmon are caught by commercial and sport fisheries in tidal waters, by Native fisheries in both tidal and non-tidal waters (<1,000 fish annually), and by in-river sport fishing; there is also in-river sport fishing for steelhead, trout, and char. In the past 10 years, commercial ocean fisheries for coho have been managed to try to avoid stocks of concern, which has resulted in low harvest of Cowichan coho. Prior to 1998, the majority of Georgia Basin coho stocks (which includes the Cowichan) were caught in the Strait of Georgia/Fraser River sport and commercial troll fisheries, and in troll, sport, and net fisheries off the west coast of Vancouver Island and in Juan de Fuca, Queen Charlotte, and Johnstone strait fisheries.

Currently, there are special restrictions on the Cowichan River to reduce the impact of sport fishing on the resource. These include area and time closures, catch quotas, catch-and-release regulations, and gear (no bait, fly-fishing only areas) and boat (speed and power) restrictions (Cowichan Recovery Plan 2005). Above Skutz Falls, fly fishing only is permitted from mid-October to end December, but in 2007 this fishery did not open until November 1 to reduce impact on Cowichan chinook runs. Creel surveys conducted annually between 2004 and 2006 indicate that the number of coho caught was low (e.g., 50 fish in 2005, and fewer in 2006), due to low angler effort (Bill Shaw, Fisheries Manager, DFO, pers. comm.).

The survival of Vancouver Island coho indicator stocks began declining in 1990 (brood year 1987). Hatchery coho continued to survive more poorly than wild stocks, but the overall trends are similar. The decline in marine survival began over a decade, with record low returns in 1996. Low marine survival appears to be the primary reason for the currently low coho returns. More recently, survival rates of northeast Vancouver Island coho stocks have stabilized somewhat, with virtually all indicator stocks improving slightly, but survival of southeast Vancouver Island stocks remains a concern due to low escapement, particularly in the Cowichan Valley (Simpson et al. 2001). Overharvesting, habitat degradation, and changing marine conditions have all contributed to decline in coho abundance (Cowichan Recovery Plan 2005). Predation by increasing numbers of seals and sea lions at the mouth of the Cowichan River may also be a factor affecting coho abundance (Burt and Robert 2002).

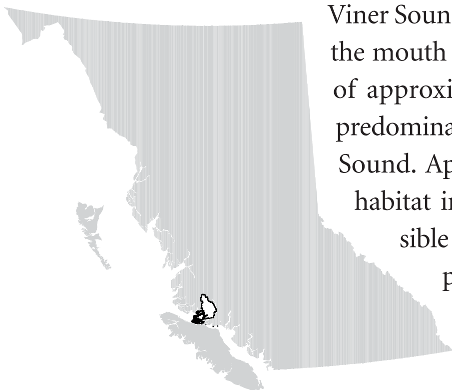
Erosion and sedimentation have caused considerable habitat degradation in the lower Cowichan River. Currently, sources of sediments and effects of sedimentation on incubating salmon eggs are being investigated by DFO, including options to control escalating erosion and sedimentation problems. In 2006, major channel realignment and bank armouring works at Stoltz Bluff were commissioned jointly by DFO, MOE, and the British Columbia Conservation Foundation to reduce erosion and sedimentation in important spawning areas in the mainstem of the river. Subsequently, a sediment-management plan for the watershed will be developed, including consideration of gravel extraction in the lower river.

Recommendations for actions that will assist in the recovery of Cowichan coho include:

- Maintain harvest rates at low levels until the stock recovers sufficiently.
- Maintain summer flows above critically low levels to provide suitable rearing habitat for juvenile coho.
- Restore and protect important spawning and rearing areas, including winter refugia (side channels, backwaters, sloughs) and riparian cover to enhance coho smolt production, for which the capacity of the Cowichan River system is estimated to range from 400,000 to a million smolts annually (Holtby 1993; Burns 2000).

Chum salmon in a small stream.

9. VINER SOUND CREEK CHUM SALMON



Viner Sound Creek is on Gilford Island, which is near the mouth of Knight Inlet. The creek drains an area of approximately 25 square kilometres and flows predominantly westward before emptying into Viner Sound. Approximately nine kilometres of suitable habitat in the mainstem and tributaries is accessible to anadromous salmonids. Coho, chum, pink, and sockeye salmon, steelhead, and cutthroat and rainbow trout occur in the system (Ebell et al. 2006). The creek supports both an early and late run of fall chum salmon. The early run, which is the main stock, arrives in late September to mid-October, whereas the late run arrives near the end of October. There are 24 chum stocks in the Bond/Knight inlets, with Viner Sound Creek accounting for up to 65 per cent of the total chum escapement in the area in past years. All escapement estimates in the area are based on foot surveys (four to six times per year).

Average escapement of Viner Creek chum has declined from approximately 32,600 in the 1953 to 1990 period to 2,400 fish in the post-1990 period, with a low of 97 fish in 1997 (Figure 17). Since 2005, escapement has rebounded slightly (range 5,400 to 9,500 fish) and may improve further if harvesting of the stock continues to be low, or ceases until the run recovers. Total returns have averaged 36,400 between 1980 and 1990, and 2,971 fish from 1991 onward (Figure 18). Harvest rates have fluctuated greatly over time, ranging from two to 49 per cent with an average 25 per cent during 1980 to 2003. In spite of consistent evidence of significant decline in returns after 1990, the harvest rate remained at an average 21 per cent from 1991 to 2003.

Prior to 1983, the management approach for Inner South Coast (ISC) chum stocks involved harvesting all chum salmon in excess of an escapement goal for all stocks combined. In practice, this approach was difficult to implement because of differences in run timing and productivity between stocks, resulting in some stocks being overharvested, while others were potentially underharvested (Ryall et al. 1999). In 1983, the Johnstone Strait Clockwork Management Strategy (CMS) (Hilborn and Ludke 1987) was implemented with the objective to rebuild ISC chum stocks by controlling the overall harvest rate. However, chum stocks in Knight Inlet have not responded well to the CMS plan (Ryall et al. 1999). Their earlier migration compared with most fall stocks and probable migration route may have bypassed most of the fisheries in Johnstone Strait, resulting in Viner Sound Creek chum salmon being a less targeted species (P. VanWill, pers. comm.).

To address the limitations of the CMS plan, a new approach for management of chum stocks in Johnstone Strait was initiated in 2002. Following extensive technical reviews and several years of discussions with First Nations, stakeholders, and the commercial fishing industry, the CMS was replaced with a stable fishing schedule

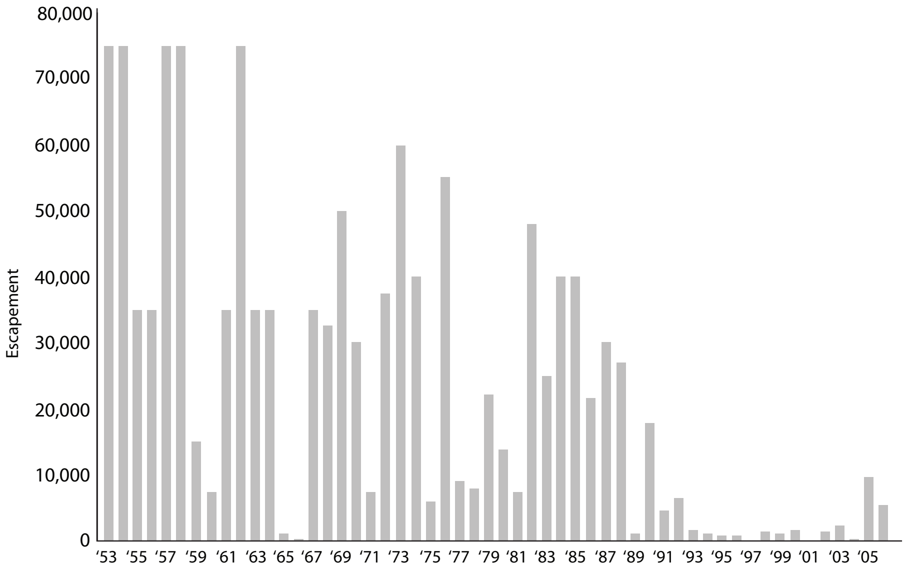


Figure 17. Trends in annual escapement estimates for Viner Sound chum salmon, 1953-2006.

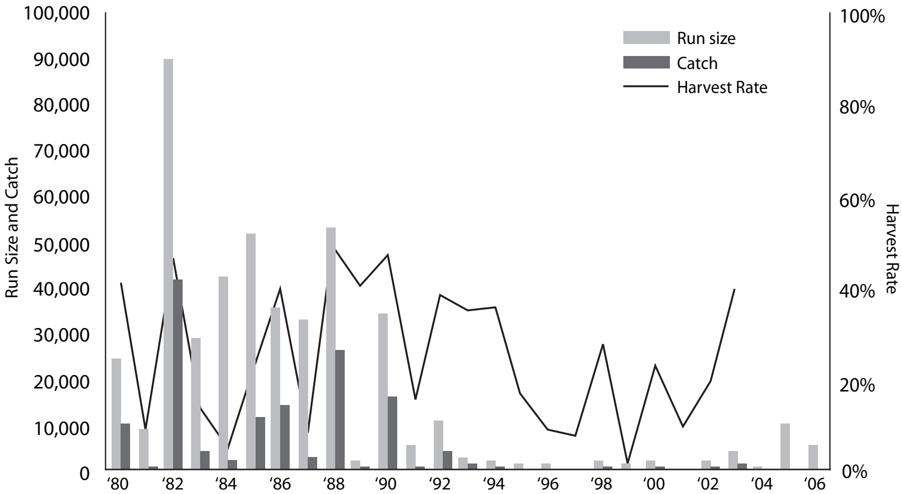


Figure 18. Trends in annual abundance, catch, and harvest rate estimated for Viner Sound chum salmon, 1980-2006. Catch data not available for 2004-2006; the catch for these years is considered to be low (P. VanWill, pers. comm.).

designed to approximate an exploitation rate of 20 per cent (Pacific Salmon Joint Chum Technical Committee 2004). The objective of this strategy was to ensure sufficient escapement and to provide more stable fishing opportunities. The exploitation rate was set at 20 per cent across all harvesters when salmon abundance was above a given critical level. Of this 20 per cent, 15 per cent was allocated to the commercial sector and the remaining five per cent was for traditional food, social and ceremonial requirements, recreational and test fishing, and a buffer for commercial exploitation. Tagging studies were conducted during 2000 to 2002 to provide information for use in assessing the effects of the new harvesting strategy on chum salmon stocks in Johnstone Strait (Pacific Salmon Joint Chum Technical Committee 2004); however, this exploitation strategy has not been tested as the fishery has been virtually nonexistent since 2004.

Logging in the watershed began in the mid 1930s, with 38 per cent of the watershed now harvested (Ebell 2006). Extensive clear-cutting has resulted in greater variability in extreme flows, altered thermal regimes, and increased sediment loads mainly due to erosion of stream banks and landslides (DFO 1988; Ebell and Cuthbert 2004). From long-term monitoring of the effects of logging in the Carnation Creek watershed (Holtby 1988; Scrivener and Brownlee 1989; Scrivener 1991), it is well documented that the impacts of logging in the Viner Sound Creek watershed can adversely affect chum salmon spawning habitat, egg-to-fry survival, and fry size, which affects survival at sea. It is expected that with regeneration of forest cover and improved logging practices, the hydrology of Viner Sound Creek and neighbouring watersheds will improve over time and assist recovery of the chum salmon population.

Viner Creek chum migrate through the Broughton Archipelago as both adults and juveniles. Recent research has evaluated the effects of salmon farms in the Broughton Archipelago on the infestation rates of sea lice on juvenile chum and pink salmon and the associated implications on fish behaviour, health, and mortality. Results have identified high infection rates of juveniles near farms (Morton et al. 2004) and that short-term mortality of juveniles is increased by infestations of only one to three lice per fish (Morton and Routledge 2005). Farm-origin lice has been shown to induce mortality in juvenile chum and pink salmon cohorts of nine to 95 per cent (Krkošek et al. 2006). An evaluation of fallowing of Broughton salmon farms in 2003 showed a decrease in the abundance of sea lice attached to juvenile wild salmon after fallowing (Morton et al. 2005), which corresponds to stronger returns of adult chum salmon to Viner Creek in 2005. Research crews have observed high sea-lice infestation rates on Viner chum salmon near a fish farm in the Burdwood Islands area (A. Morton, pers. comm.).

Recommended activities that will assist in recovery of Viner Sound Creek chum salmon include:

- Maintain harvest at low to zero levels while stock abundance remains low, even in years when favourable ocean conditions result in improved returns, to allow escapement to build up sufficiently.
- Continue with fry releases from Scott Cove Hatchery to improve stock status (P. Van Will, pers. comm.).
- Undertake restoration works to improve channel stability and in-stream habitat to enhance chum salmon fry production.
- Provide a migration corridor for juvenile salmon with reduced sea-lice impacts by moving or fallowing farms.

10. KEOGH RIVER STEELHEAD

The Keogh River watershed (129 square kilometres), located near Port Hardy on the east coast of Vancouver Island, flows in a northeasterly direction for approximately 35 kilometres before emptying into Queen Charlotte Strait. River flow is influenced mainly by rainfall and varies greatly with season. The lowest flows are in summer (as low as 0.1 cubic metres), and highest flows are in late autumn through winter (>200 cubic metres). The stream flow is usually quite clear with low levels of dissolved solids and nutrients. Forest cover of the watershed is dominated by western red cedar and western hemlock, with slightly more than 50 per cent having been harvested (clearcut) in the past 50 years (Bruce Ward, pers. comm.). Fish populations in the watershed include pink, chum, and coho salmon, winter-run steelhead, anadromous and resident Dolly Varden and cutthroat trout, kokanee, and a few non-salmonid species (cottids, sticklebacks, lampreys).

Fish-counting fence on the Keogh River.

Keogh steelhead rear in fresh water for two to four years before migrating to the sea, where they feed and grow for one to four years and then return to spawn; approximately 10 per cent of the spawning population are repeat spawners (Ward and Slaney 1988). Owing to the remote location of the watershed, this stock is not subjected to heavy angling pressure. Prior to catch-and-release regulations introduced to Vancouver Island in 1980, the estimated annual harvest based on creel surveys was about five per cent (Ward and Slaney 1988). Some steelhead kelts are taken as a bycatch in commercial salmon fisheries in late spring (Evans 1979).

The Keogh River has been the site of monitoring of winter-run steelhead outmigrating smolts and adult returns since 1976 via operation of a counting fence near the river mouth. Adults migrating upstream are usually trapped from February to May, and the total number of spawners each year is estimated by marking males migrating upstream and capturing kelts (of both sexes) migrating downstream from March to June. More recently, information on smolts and adults of other salmonids (coho salmon, Dolly Varden, cutthroat trout) has also been gathered at this site. This facility has provided valuable long-term data on steelhead smolt and adult runs and the opportunity to examine the influence of smolt size on marine survival. In addition, recent tracking of sonically tagged steelhead smolts from the Keogh River and Waukwaas River (which lies adjacent to the Keogh, but drains to the west coast) in coastal environments may help explain why marine survival of west coast Vancouver Island steelhead stocks is considerably better than that of east coast stocks (McCubbing and Ward 2006).

Estimates of the adult steelhead runs to the Keogh River for the past 30 years show a marked change in abundance between the 1976 to 1990 and 1991 to 2006 periods, with the runs declining from an average 1,168 to 172 fish (Figure 19).

Although run size has varied considerably between years prior to 1990 (range 209 to 2,939 fish), since then the runs have been consistently low (range 25 to 540 fish), with fewer than 100 fish in several of these years.

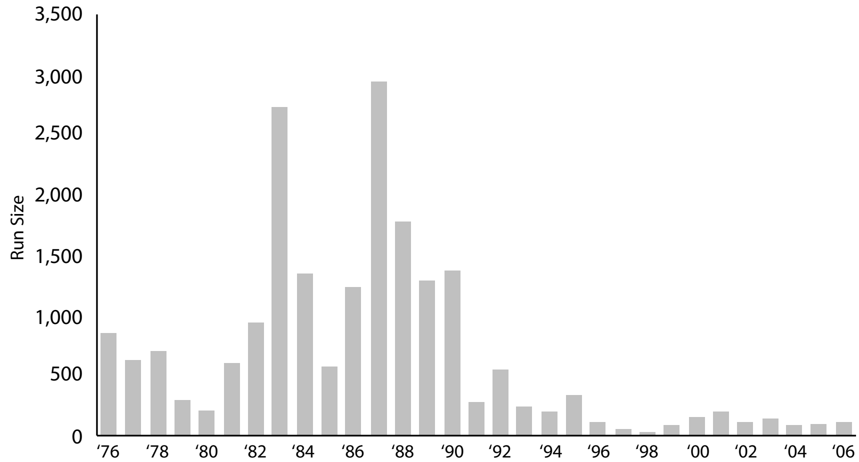


Figure 19. Trends in annual run estimates for Keogh River steelhead adults, 1976-2006.

The abundance of wild smolts has varied substantially between 1977 and 1993 (range 2,100 to 13,880 fish), but after 1993, with the exception of 2003, smolt production has been consistently low (Figure 20). Smolt-to-adult survival declined from an average 15 per cent in the pre-1990 period to four per cent in the post-1990 era. The relationship between smolt numbers and adult returns changed appreciably in 1990, and the returns since then are no longer correlated with smolt size as they were previously (Ward 2000). Fertilizing of the oligotrophic waters of the Keogh may be a way of enhancing smolt production, as was shown in the 1984 to 1986 trials, in which fertilizing of the mainstem increased smolt numbers by 65 per cent, but after it was discontinued smolt numbers dropped to previous levels. The recent severe declines in chum and pink (odd year) salmon runs may have contributed to nutrient deficiency (mainly phosphorus) in the Keogh River.

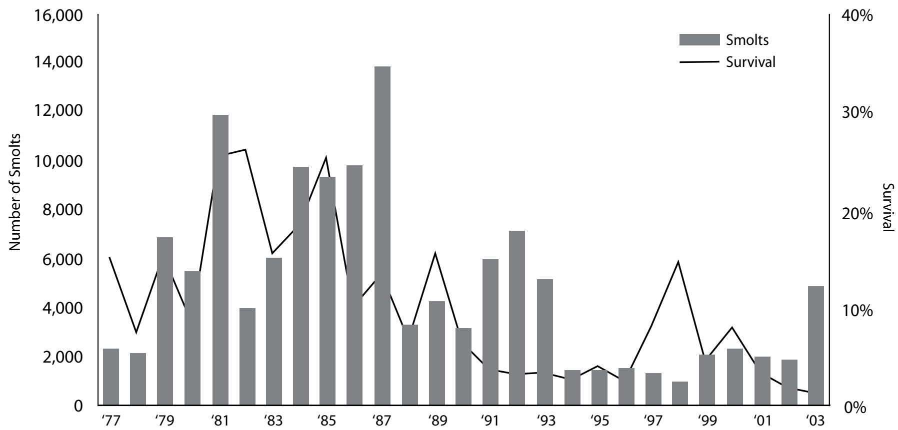


Figure 20. Trends in Keogh River steelhead smolt numbers and smolt-adult survival, 1977-2003. Smolt numbers for 2004-2006 are not shown as the adult returns for these years are not yet available.

Impacts to the Keogh River watershed likely affecting the steelhead population include extensive riparian logging, which has left major reaches of the river deficient in large woody debris (LWD) – an important ingredient of steelhead habitat – and considerable sedimentation in some sections attributable to logging activities and severe storms and landslides (Ward et al. 2006). While little can be done to improve the currently low marine survival of steelhead, several watershed restorative works are underway to enhance habitat for salmonids. They include installation of in-stream habitat structures, development of off-channel ponds, addition of nutrients, and storm-proofing and stabilizing logging roads (Bruce Ward, pers. comm.).

Data from the annual monitoring programs for Keogh steelhead represent one of the longest and most reliable time series of marine survival estimates available for Pacific salmon and steelhead in Canada. As such, Keogh steelhead and its associated monitoring efforts are critical for tracking long-term trends in marine survival and assessing the impact of global warming on salmon and steelhead.

Solutions

The David Suzuki Foundation proposes the following solutions to protect and conserve salmon stocks in Canada, based on this report and other works published by the Foundation.

Enforce habitat regulations

Habitat loss or degradation was identified as a key factor in the decline of most of the salmon profiled in this report. Recent and ongoing work by the David Suzuki Foundation (2006, 2007) has shown that habitat destruction continues in British Columbia. Lack of enforcement capacity, including both resources and personnel, has been identified as a key factor in this discrepancy.

KEY RECOMMENDATIONS:

- Double the number of habitat enforcement officers, with the powers of inspection and ticketing, in the Pacific Region.
- Leave some water for the fish by enforcing minimum flow standards for salmon-bearing streams and implementing water-use plans across British Columbia.

Fish selectively

Salmon are a relatively productive resource capable of supporting sustainable fisheries. However, many salmon stocks cannot withstand historic fishing pressures, and the recovery of threatened populations requires reduced fishing to allow rebuilding. Ultimately, a selective fishing approach maximizes the abundance of salmon available for harvest.

KEY RECOMMENDATION:

- Implement economic incentives for the use of selective fishing methods, including moving the harvest away from mixed-stock areas and supporting selective fishing-gear types.

Precautionary Management

Climate change is altering all of the environments where salmon live, from small streams to the Pacific Ocean. Elevated freshwater temperatures and altered ocean conditions are already affecting salmon in British Columbia, and poor marine survival has been implicated in the decline of profiled stocks. Billions of hatchery and enhanced salmon are released into the Pacific Ocean every year. The use of historic abundance data to predict and manage fisheries is inappropriate for present conditions. Protecting habitat is much cheaper than restoring degraded habitat and provides a much better guarantee that it will work for salmon.

KEY RECOMMENDATIONS:

- Use in-season monitoring information to guide fishing decisions, rather than opening fisheries based on predicted returns using historic stock/recruit relationships.
- Prioritize the protection of unaltered salmon habitat over the use of habitat compensation and restoration measures.
- Conduct an independent review of the Salmon Enhancement Program to ensure enhancement activities are informed by the latest scientific information and support the conservation and recovery of salmon at risk.

Legislated protection for endangered stocks

In 2002, Canada passed the Species at Risk Act (SARA). SARA provides legislated protection of species from directed harm (e.g., fisheries), protects critical habitat, requires recovery plans to be implemented, and provides tools (i.e., funding) for recovery. So far, four salmon stocks have been scientifically assessed as threatened or endangered, including two of the stocks profiled in this report (Cultus sockeye and Interior Fraser coho). Three have been rejected for listing under SARA.

KEY RECOMMENDATIONS:

- List salmon assessed as threatened or endangered under SARA, including those previously rejected for listing.
- Protect salmon before they reach threatened status by reducing fishing and habitat impacts on declining stocks.

Implementation of the Wild Salmon Policy

Fisheries and Oceans Canada released *Canada's Policy for Conservation of Wild Pacific Salmon* (aka the Wild Salmon Policy) in 2005. This policy prioritizes the protection of salmon diversity and provides a key framework for implementing the other solutions presented here. However, it has not been fully implemented and needs more political and financial support.

KEY RECOMMENDATIONS:

- Provide five years of annual funding of at least $3 million dollars to support Wild Salmon Policy implementation.
- Fisheries and Oceans Canada should report on the status of salmon and salmon habitat, as required by the Wild Salmon Policy, and clearly identify and communicate the direct management actions taken in support of the policy to protect Pacific salmon.

REFERENCES

1. LAKELSE LAKE SOCKEYE SALMON

Cox-Rogers, S., J.M.B. Hume, and K.S. Shortreed. 2004. *Stock status and lake-based production relationships for wild Skeena River sockeye salmon*. Fisheries and Oceans Canada CSAS Research Document 2004/10.

Cummings, B. 2002. *Assessment of changes in total phosphorous in Lakelse Lake, BC: a paleolimnological assessment.*

Foerster, R.E. 1968. *The sockeye salmon, Oncorhynchus nerka*. Bull. Fish. Res. Board Can. 162:422p.

Lakelse Lake Sockeye Recovery Plan. 2005. R*ecovering Lakelse Lake Sockeye Salmon – Lakelse Lake Sockeye Recovery Plan* prepared by Lakelse Watershed Society, Kitselas First Nation, Terrace Salmonid Enhancement Society, BC Ministry of Water, Land and Air Protection, BC Timber Sales, and Fisheries and Oceans Canada. 18 p.

Shortreed, K.S., J.M.B. Hume, K.F. Morton, and S.G. MacLellan. 1998. *Trophic status and rearing capacity of smaller sockeye nursery lakes in the Skeena River system*. Can. Tech. Rep. Fish. Aquat. Sci. 2240: 78 p.

Skeena Fisheries Commission. 2003. *Conserving Lakelse fish populations and their habitat. Lakelse Watershed Fish Sustainability Plan*, Stage II briefing backgrounder.

2. SMITH INLET SOCKEYE SALMON

Cox-Rogers, S., J. Hume, and J. Sturhahn. 2005. *Biological escapement goals for Smith Inlet (lake) sockeye*, September 2005.

Hyatt, K.D., D.P. Rankin, and B. Hanslit. 2000. *Acoustic and trawl based estimates of juvenile sockeye salmon (Oncorhynchus nerka) production from 1976-1999 brood year adults returning to Smith Inlet and Long Lake, British Columbia.* PSARC Working Paper S2000-21.

Riddell, B. 2004. *Pacific salmon resources in central and north coast British Columbia*. Vancouver, BC, Pacific Fisheries Resource Conservation Council. 155p.

Rivers and Smith Inlets Salmon Ecosystem Planning Society. 2003. *Rivers and Smith Inlets Ecosystem Recovery Plan*. Prepared for Pacific Salmon Endowment Fund Society, December 2003. 61p.

Rutherford, D.T., and C.C. Wood. 2000. *Assessment of Rivers and Smith Inlets sockeye salmon with commentary on small sockeye salmon stocks in Statistical Area 8*. Fisheries and Oceans Canada, Stock Assessment Sec. Res. Doc. 2000/162. Ottawa, Ontario.

Shortreed, K.S., K.F. Morton, K. Malange, and J.M.B. Hume. 2001. *Factors limiting juvenile sockeye production and enhancement potential for selected BC nursery lakes.* Can. Sci. Adv. Sec. Res. Doc. 2001/098.

3. NIMPKISH RIVER SOCKEYE SALMON

Nimpkish Resource Management Board. 2003. *Nimpkish Watershed Salmon Recovery Plan.* Prepared for Pacific Salmon Foundation, February 2003. 145p.

Weinstein, M. 1991. *A History of Resource Management from Aboriginal Times to the 1980s on Part of the Traditional Lands of the Nimpkish People*. 323 p.

4. CULTUS LAKE SOCKEYE SALMON

Cooper, A.C. 1952. *Downstream migrant study Cultus Lake.* Int. Pac. Salmon. Fish. Comm., unpublished. 12p.

COSEWIC. 2003. *COSEWIC assessment and status report on the sockeye salmon Oncorhynchus nerka (Cultus population) in Canada.* Committee on the Status of Endangered Wildlife in Canada. ix + 57 pp.

Foerster, R.E. 1929a. *An investigation of the life history and propagation of the sockeye salmon (Oncorhynchus nerka) at Cultus Lake, British Columbia.* No. 1. Introduction and the run of 1925. Contributions to Canadian Biology and Fisheries 5 (1): 3-35.

Foerster, R.E. 1929b. *An investigation of the life history and propagation of the sockeye salmon (Oncorhynchus nerka) at Cultus Lake, British Columbia.* No. 2. Introduction and the run of 1926. Contributions to Canadian Biology and Fisheries 5 (2): 39-53.

Foerster, R.E. 1929c. *An investigation of the life history and propagation of the sockeye salmon (Oncorhynchus nerka) at Cultus Lake, British Columbia.* No. 3. Introduction and the run of 1926 and 1927. Contributions to Canadian Biology and Fisheries 5 (3): 57-82.

Foerster, R.E. 1934. *An investigation of the life history and propagation of the sockeye salmon (Oncorhynchus nerka) at Cultus Lake, British Columbia.* No. 4. The life history cycle of the 1925 year class with natural propagation. Contributions to Canadian Biology and Fisheries 8 (27): 345-355.

Foerster, R.E. 1936. *An investigation of the life history and propagation of the sockeye salmon (Oncorhynchus nerka) at Cultus Lake, British Columbia.* No. 5. The life history cycle of the 1926 year class with artificial propagation involving the liberation of free-swimming fry. J. Bio. Bd. Can. 2 (3): 311-333.

Healy, M.C. 1980. The ecology of juvenile salmon in Georgia Strait, British Columbia. In: *Salmonid ecosystems of the North Pacific.* McNeil, W.J. and D.C. Himsworth (eds). Oregon State University Press.

Howard, G.V. 1948. A study of the tagging method in the enumeration of sockeye salmon populations, p. 9-66 *In*: *Problems in enumeration of populations of spawning sockeye salmon: International Pacific Salmon Fisheries Commission*, Bulletin II.

Ricker, W.E. 1935. *Studies of the limnological factors affecting the propagation and survival of the sockeye salmon (Oncorhynchus nerka) in Cultus Lake, British Columbia.* PhD thesis, University of Toronto.

Ricker, W.E. 1937. *Physical and chemical characteristics of Cultus Lake, British Columbia.* J. Biol. Bd. Can. 3 (4):363-402.

Ricker, W.E. 1938. *A comparison of seasonal growth rates of young sockeye salmon and young squawfish in Cultus Lake.* Fisheries Research Board of Canada. Progress Reports of the Pacific Biological Station 36: 3-5.

Ricker, W.E. 1952. *Numerical relations between abundance of predators and survival of prey.* Can. Fish. Culturist. No. l3: 5-9.

St-Hilaire, S., S.M. Burrows, M. Higgins, D. Barnes, R. Devlin, R. Withler, J. Khattra, S. Jones, and D. Kieser. 2001. *Epidemiology of Parvicapsula minibicornis in Fraser River sockeye salmon.* Unpublished.

Stock Assessment and Fisheries Management Work Group. 2002. *Cultus Lake Sockeye Recovery Planning Process.* Prepared by Fisheries and Oceans Canada, Pacific Salmon Commission and IAS Limited.

5. NIMPKISH RIVER CHINOOK SALMON

Nimpkish Resource Management Board. 2003. *Nimpkish Watershed Salmon Recovery Plan.* Prepared for Pacific Salmon Foundation, February 2003. 145p.

6. MIDDLE NORTH THOMPSON RIVER COHO SALMON

DFO. 2005. *Recovery assessment report for interior Fraser coho salmon (Oncorhynchus kisutch).* DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2005/061.

Interior Fraser Coho Recovery Team. 2006. *Conservation strategy for coho salmon (Oncorhynchus kisutch), Interior Fraser River populations.* Fisheries and Oceans Canada. 132p.

8. COWICHAN RIVER COHO SALMON

Argue, A.W., B. Hillaby, and C.D. Shepard. 1986. D*istribution, timing, change in size, and stomach contents of juvenile Chinook and coho salmon caught in Cowichan estuary and bay, 1973, 1975, 1976.* Can. Tech. Rep. Fish. Aquat. Sci. 1431.

Aro, K.V., and M.P. Shepard. 1967. *Pacific salmon in Canada. Pp 225-327 in Salmon of the north Pacific Ocean – Part IV. Spawning populations of north Pacific salmon.* Intern. North Pac. Fish. Comm. Bull. 23.

Burns, T. 2000. *CRVD production plan: a primer*.

Burt, D.W. and C.B. Robert. 2002. *A review of environmental factors affecting the production of Cowichan River Chinook salmon.* Fisheries and Oceans Canada, Oceans and Community Stewardship, Nanaimo, BC.

Cowichan Recovery Plan. 2005. Prepared for the Cowichan Tribes Treaty Department. Prepared by LGL Limited, 9768 Second Street, Sidney, BC, V8L 3Y8.

CETF. 1980a. *Cowichan Estuary Task Force Report.* Prepared by the Cowichan Estuary Task Force for the Environment and Land Use Committee Secretariat, Victoria, BC.

Holtby, L.B. 1993. *Escapement trends in Mesachie Lake coho salmon with comments on Cowichan Lake coho salmon*. Fisheries and Oceans, Canada, PSARC Working Paper S93-3.

Lill, A.F., D.E. Marshall, and R.S. Hooton. 1975. *Conservation of fish and wildlife of the Cowichan-Koksilah flood plain.* Environment Canada, Fisheries and Marine Service, and the BC Department of Recreation and Conservation, Fish and Wildlife Branch.

Lister, D.B., C.E. Walker, and M.A. Giles. 1971. *Cowichan River Chinook salmon escapements and juvenile production, 1965-67.* Department of Fisheries and Forestry, Tech. Rep. 1971-3.

MEP. 1986. *Cowichan-Koksilah water management plan.* Ministry of Environment and Parks, Planning and Assessment Branch, Vancouver Island Region, Nanaimo, BC.

Neave, F. 1949. *Game fish population of the Cowichan River.* Fish. Res. Bd. Can. Bull. 134:32p.

Simpson, K., D. Dobson, R. Semple, S. Lehmann, S. Baillie, and I. Matthews. 2001. *Status in 2000 of Coho Stocks Adjacent to the Strait of Georgia.* Canadian Science Advisory Secretariat. Research Document 2001/144.

9. VINER SOUND CREEK CHUM SALMON

Department of Fisheries and Oceans. 1988. *Pacific Region Salmon Stock Management Plan. Inner South Coast (Including Fraser River).* Vol. 1. 195 pp.

Ebell, J. 2006. *Viner River Fish Habitat Restoration Habitat 2005 Compendium.* Prepared by Streamline Consulting Ltd. Prepared for International Forest Products Ltd.

Ebell, J. and I.D. Cuthbert. 2004. *Overview and Level 1 habitat Assessment of the Viner River.* International Forest Products Ltd. Campbell River. 87 pp.

Hilborn, R. and Leudke, W.H. 1987. *Rationalizing the irrational: a case study in user group participation in Pacific salmon management.* Can. J. Fish. Aquat. Sci. 44: 1796-1805.

Holtby, L.B. 1988. *Effects of logging on stream temperatures in Carnation Creek, British Columbia and associated impacts on coho salmon (Oncorhynchus kisutch).* Can. J. Fish. Aquat. Sci. 45:502-515.

Krkošek, M., M. A. Lewis, A. Morton, L. N. Frazer, and J. P. Volpe. 2006. *Epizootics of wild fish induced by farm fish.* Proceedings of the National Academy of Science 103:15506-15510.

Morton, A., R. Routledge, C. Peet, and A. Ladwig. 2004. Sea lice (Lepeophtheirus salmonis) infection rates on juvenile pink (Oncorhynchus gorbuscha) and chum (Oncorhynchus keta) salmon in the nearshore marine environment of British Columbia, Canada. *Canadian Journal of Fisheries and Aquatic Sciences* 61:147-157.

Morton, A., and R. Routledge. 2005. *Mortality rates for juvenile pink Oncorhynchus gorbuscha and chum O. keta salmon infested with sea lice Lepeophtheirus salmonis in the Broughton Archipelago.* AlaskaFishery Research Bulletin 11:146-152.

Morton, A., R. D. Routledge, and R. Williams. 2005. Temporal patterns of sea louse infestation on wild Pacific salmon in relation to the fallowing of Atlantic salmon farms. *North American Journal of Fisheries Management* 25:811-821.

Pacific Salmon Commission Joint Chum Technical Committee. 2004. *2004 Post-Season Summary Report.* TCCHUM (06)-1.

Ryall, P., C. Murray, V. Palmero, D. Bailey, and D. Chen. 1999. *Status of clockwork chum salmon stock and review of the clockwork management strategy.* Canadian Stock Assessment Secretariat Research Document 99/169.

Scrivener, J.C. 1991. An update and application for the production model for Carnation Creek chum salmon. In *Proceedings of the 15th Northeast Pacific Pink and Chum Workshop, February 27–March 1, 1991, Parksville, BC.* Edited by B. White and I. Guthrie. Available from the Pacific Salmon Commission Vancouver, BC. pp 210-219.

Scrivener, J.C., and M.J. Brownlee. 1989. *Effects of forest harvesting on the spawning and incubation of chum salmon (Oncorhynchus keta) and coho salmon (O. kistuch) in Carnation Creek, British Columbia.* Can. J. Fish. Aquat. Sci. 46: 681-696.

10. KEOGH RIVER STEELHEAD

Evans, L.K. 1979. *Incidental catches of steelhead trout in the commercial salmon fisheries of Barkley Sound, Johnstone Strait and the Dean and Bella Coola rivers area.* Prov. BC Fish Wild. Fish. Tech. Circ. No. 39: 30 p.

McCubbing, D.J.F., and B.R. Ward. 2006. *Adult steelhead trout and salmonid smolt migration at the Keogh River, BC, during winter and spring, 2005.* Habitat Conservation Trust Fund Contract Number: CBIO 4051. 45 p.

Ward, B.R. 2000. *Declivity in steelhead (Oncorhynchus mykiss) recruitment at the Keogh River over the past decade.* Can. J. Fish. Aquat. Sci. 57: 298-306.

Ward, B.R., and P.A. Slaney. 1988. *Life history and smolt-to-adult survival of Keogh River steelhead trout (Salmo gairdneri) and the relationship to smolt size.* Can. J. Fish. Aquat. Sci. 45: 1110-1122.

Ward, B.R., Slaney, P.A., and D.J.F. McCubbing. 2006. *Watershed restoration to reconcile fisheries and habitat impacts at the Keogh River in coastal British Columbia.* American Fisheries Society Symposium, 2006: 587-602.

The David Suzuki Foundation is working on many fronts to support the long-term health of wild Pacific salmon. We ensure that government policies are strong and well implemented and that efforts to certify fish for the marketplace are meaningful.

The declines of salmon profiled in *An Upstream Battle: Declines in 10 Pacific Salmon Stocks and Solutions for their Survival* are symptomatic of the challenges facing Pacific salmon in Canada. By focusing on specific examples of salmon stocks or populations in decline, this report analyzes these challenges in greater detail and provides guidance on recovery.

Current scientific evidence demonstrates that the diversity of salmon and their habitat must be protected in order for the fisheries to remain resilient and sustainable. The critical need to improve the management of salmon fisheries and their habitat is greater than ever. Fortunately, the solutions are available.

The David Suzuki Foundation is committed to sustainability within a generation in Canada. Abundant stocks of wild Pacific salmon are a vital part of a sustainable, prosperous future.

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