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Hatchery and wild percentages of coho salmon in the Strait of Georgia are related to shifts in species dominance

by

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Abstract

The Strait of Georgia is the major rearing area for juvenile Pacific salmon on the west coast of Canada. Historically, there have been major commercial and recreational fisheries for all five species of Pacific salmon in the strait. In recent years, fisheries for coho have collapsed. At the same time abundances of other species increased. Presently there may be three and a half times more juvenile Pacific salmon in the strait than in the past. Our studies of the hatchery percentages of wild and hatchery coho indicate that early food production for juvenile salmon may be shifting the Strait of Georgia to an ecosystem that is more favourable for pink, chum and sockeye salmon and less favourable for coho and chinook salmon.

Introduction

The Strait of Georgia is a rearing area for Pacific salmon that historically contributed to about one third of the total Canadian Pacific salmon catch. The major production comes from stocks that spawn in the Fraser River. Coho salmon in the Strait of Georgia traditionally supported a commercial fishery and a major recreational fishery. However, beginning in the 1990s, escapements declined as marine survival declined resulting in management action that further reduced fishing (Beamish et al. 2004). Furthermore, since about the mid 1990s, coho salmon would leave the Strait of Georgia in the fall and, except in 2001, they did not return until early fall of the next year. This behaviour occurred for hatchery and wild coho salmon and virtually ended the sport and commercial fishery (Fig. 1).

Our research surveys over the past ten years provided estimates of the percentage of hatchery and wild coho salmon in the Strait of Georgia (Sweeting et al. 2003). It is this estimate along with the trends in abundance of pink, chum and sockeye salmon that provide an explanation of why coho salmon abundances have declined. In this report, we summarize the information used to develop the explanation. There are critical gaps in our interpretation, but there also is sufficient information to show that improved management including forecasting requires an understanding of the mechanisms that regulate the productivity of coho and other Pacific salmon in the ocean.

Methods

The gear and survey methods have been described in Beamish et al. (2000). The method used to determine the percentage of hatchery and wild coho salmon was similar to the method described in Sweeting et al. (2003). In 1997, large numbers of coho were marked by removing a pelvic fin. Beginning in 1998, large numbers of coho salmon produced in Canadian and United States hatcheries had the adipose fin removed, which is commonly referred to as "an adipose clip." A small percentage (usually around 5%) of these adipose-fin clipped fish also receives a coded-wire tag (CWT) which allows the origin of the tagged fish to be determined. In our surveys we identify all clipped and tagged coho salmon. We use the tagged fish to separate coho salmon released in Canada from those released from hatcheries in Puget Sound. We know how many coho smolts are released from Canadian hatcheries and we use the clipping percentage to expand the observed number of clipped fish in our survey sample to determine the number of Canadian hatchery fish in our survey catches. We divide this expanded number by the total survey catch of Canadian hatchery and wild coho salmon to determine the hatchery percentage. We did not correct for possible tagging mortality or detection errors, as was done in Sweeting et al. (2003).

Shifting Dominance

An estimate of the number of juvenile Pacific salmon entering the Strait of Georgia was made for the years 1967 to 1976 and 1993 to 2003 by calculating the number of juveniles needed to produce the total returns. The number of juvenile chinook and coho from 1993 to 2003 was calculated using total hatchery releases and expanding by the percentage of hatchery juveniles in the July surveys. The catch and escapement data for 1967-1976 for all species of salmon was obtained from Archibald and Graham (1981). Sport catch data for 1967-1976 for coho and chinook salmon was from Argue et al. (1983). No sport catch was included for pink, chum and sockeye salmon for this period. Commercial and sport catch data for 1993-2003 for all species of salmon was obtained from Fisheries and Oceans commercial and recreational catch statistics webpages (www.pac.dfo-mpo.gc.ca/sci/sa/Commercial/default_e.htm, www.pac.dfo-mpo.gc.ca/sci/sa/Recreational/default_e.htm). Escapement data for pink and sockeye salmon from 1993-2003 is for the Fraser River as this system represents the majority of pink and sockeye returning to the Strait of Georgia. Escapement data for this period for chum salmon were obtained from the Salmon Escapement Database Source (sci.info.pac.dfo.ca/sein_prod/noSEDS%20v1.0/noSEDS%20v1.htm). Chum salmon return to numerous rivers around the Strait of Georgia but escapement estimates have only been collected consistently on 13 of the rivers. These rivers represent approximately 68% of the returns in years when 13 rivers were surveyed. Total return is the sum of commercial catch, sport catch and escapement.

<u>Pink salmon</u>

Pink salmon have a two year life cycle with fish spending one winter in the ocean and returning to the river the following summer/fall, therefore, total return was lagged one year to correspond to the year of ocean entry. A marine survival of 3.1% was used for pink salmon during all the historical period. This is an average of the marine survival observed for Fraser River pink salmon from brood years 1961-1979 (International Pacific

Salmon Fisheries Commission 1986). For 1993-2003, the marine survival estimate was increased by 50% to 4.7%. This increase in survival was made in consideration of the exceptional returns of pink salmon to the Fraser River in 2001 and 2003 (Fig. 2) and estimated high marine survival in the central coast for pink salmon returning in 2003 (Beamish et al. 2006).

Coho salmon

The majority of coho salmon spend one winter in the ocean prior to returning to the rivers to spawn. There is a percentage of coho that will return as "jacks" following their first summer at sea; however, these are not considered in this calculation. Therefore, the total return is lagged one year to match the year of ocean entry. An average marine survival of 15.5% from 1972 to 1977 brood years (Perry 1995) was used for all historical years. For the 1993 to 2003 period, we applied an average hatchery percentage of 49.6% which was determined in our study.

Chum salmon

Chum salmon return to rivers entering the Strait of Georgia after 1-5 winters in the marine environment. Studies by Beacham and Murray (1987) indicated that three year olds dominated the chum salmon returning to the Fraser River (61.4%) and to East Vancouver Island (72.2%) in 1981 to 1985. Earlier studies by Pritchard (1943) suggested that two year olds and four year olds could also comprise 16 – 56% of the returns during the period from 1916 – 1935. However, for this study chum salmon were assumed to return after 3 years in the marine environment. Therefore, the catch year is lagged three years to match the year of ocean entry. An average marine survival of 1.2% calculated for returns to the Fraser River for the period 1961-1974 (Beacham and Starr 1982) was applied to the data from 1967-1976. The marine survival of 0.34% for 1993 to 2003 was calculated using total releases and recoveries from several hatcheries, and is similar to that described for coho salmon.

Sockeye salmon

Most sockeye salmon return to rivers entering the Strait of Georgia after two winters in the marine environment (Burgner 1991); therefore, the total return is lagged two years to match the year of ocean entry. An average marine survival of 8.9% for the period 1967-1976 and 5.8% for the period 1993-2003 (www.psc.org) was applied to each year.

Chinook salmon

For this study we assumed all chinook salmon return after three years in the ocean and therefore total return is lagged three years to match the year of ocean entry. An average marine survival of 4.0% from 1972-1976 brood years (Perry, 1995) was applied to all years of the historical data. The number of juveniles from 1993-2003 period was calculated using a hatchery percentage that had been calculated by Beamish et al. (1995) for juvenile chinook salmon in 1992 and 1993. The total hatchery releases were multiplied by this percentage to estimate the total number of chinook entering the Strait of Georgia.

Results

We completed 1,771 sets from 1997 to 2006 that captured 32,668 coho salmon. The largest percentages of Canadian hatchery coho salmon (71.8%) occurred in July 1997 (Fig. 3A). The percentage of hatchery coho salmon then declined steadily through to 2005 and 2006. The percentage of hatchery coho in the September surveys followed a similar trend with 1997 having the highest hatchery contribution. There was a declining trend after 1997 with the lowest percentages occurring in 2004 and 2006 (Fig. 3B).

Estimates of abundances in July ranged from 10,960,000 in 2000 to 820,000 in 2005 (Table 1). Abundances in September were lower and not shown in this report. The abundance of wild coho salmon was estimated as the total abundance multiplied by the percentage that was wild fish. Abundances of hatchery coho increased in July from 1997 to 2000. The abundances decreased steadily after 2000. In July 2006, the number of wild coho salmon in the survey increased to 64.6% or 3,983,000 juvenile coho (Fig. 4A). The percentage of wild coho salmon in September increased from 1997 to 2001 and then decreased to 2005 (Fig. 4B). Beginning about 2002, wild coho became more abundant than hatchery coho. The trends in abundances of hatchery and wild coho were similar in the July and September surveys.

<u>Hatchery releases</u>

Releases of coho salmon from hatcheries around the Strait of Georgia increased from the early 1970s to the early 1980s (Fig. 5). From about the mid 1980s to 2002, the total number of smolts produced increased gradually to about 11 million smolts. Releases then decreased to about 8 million smolts in 2004. Final numbers for 2005 and 2006 are not available.

The average date that coho salmon are released from hatcheries between 1985 and 2005 was May 9 (Fig. 6). There has been very little variation (±3.8 SD) in this mean date in the past 20 years. The estimated average size of these hatchery coho salmon has also remained constant with the average release size from 1975 to 2005 being 20.4 cm (data not shown).

Index of juvenile production

The production of pink and sockeye salmon from the Fraser River stocks is shown in Figs. 2 and 7. Production was low in the 1970s, but has increased in recent years. Pink salmon production is now at historic high levels. Because there is relatively little fishing effort, the recent escapements are the highest recorded and may the highest in a century. The returns of chum salmon to the monitored streams indicate increases in returns in recent years with the highest escapement occurring in 1998 (Fig. 8).

We estimated that the combined abundance of pink, chum and sockeye juveniles entering the Strait of Georgia in 1993-2003 may be about 3.5 times the average abundance from 1967-1976 (Fig. 9). The average annual abundance of coho and chinook juvenile salmon increased by about 2.9 times from the numbers for 1967-1976.

Discussion

The change in the trend of hatchery and wild percentages of coho salmon in the late 1990s was associated with increased production of pink, chum and sockeye salmon. Our estimate of juvenile abundance indicated that perhaps three and one half times more juveniles of these species were entering the Strait of Georgia, compared to abundances several decades earlier. The large abundances of pink salmon returning to the Fraser River in 2001 and 2003 clearly showed that their productivity had improved. The large return in 2001 resulted from a very low escapement in 1999, indicating that ocean conditions were favourable for survival. The improved production of the three species is an indication that the juveniles experienced favourable feeding conditions when they entered the Strait of Georgia.

We concluded that the increases in abundances show that there was a change in the Strait of Georgia ecosystem that resulted in more prey being available to first feeding juvenile Pacific salmon (and other species) earlier in the year. The decline in hatchery percentages of coho was associated with reduced marine survival of hatchery fish (Fig. 10). There was a reduction in the number of coho salmon released from hatcheries, but the abundance estimates of hatchery fish in July showed that there was a decreasing trend in marine survival. At the same time, there was an increase in the abundance of wild coho salmon. The constant release period provides a clue to understanding what was occurring. Pink, chum and sockeye juveniles enter the Strait of Georgia earlier that most coho and chinook salmon. Conditions that were favourable for salmon marine survival were progressively occurring earlier in the year, resulting in progressively poorer survival of coho salmon that entered the ocean later in the year. The fixed release date for hatchery coho salmon increased the impact, as the hatchery coho salmon were prevented from entering earlier. We speculate that the improved production of wild coho was occurring because they were entering the ocean earlier through natural processes. In general, the Strait of Georgia ecosystem was shifting from a coho and chinook salmon ecosystem to a pink, chum and sockeye salmon favourable ecosystem.

We believe that the mechanism affecting marine survival of coho is related to the amount of growth early in the marine period. We observed a relationship of coho salmon (r^2 = 0.78) between high abundance in July and large average size (except 2005). When abundance in July was low and the fish were small, the mortality between about mid May and mid July was high as indicated by the difference in the number of coho entering the Strait and the number in our surveys.

Although our research seems to create more questions, it is apparent that improving the understanding of the dynamics of the marine phase in Pacific salmon improves our understanding of the factors regulating the return of adult salmon. Thus, we suggest that it is timely to expand these small regional studies on the mechanisms regulating the ocean productivity of the various species of Pacific salmon to large-scale, integrated research programs.

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Fig. 1. Estimated catch of coho salmon in the recreational fishery in the Strait of Georgia.

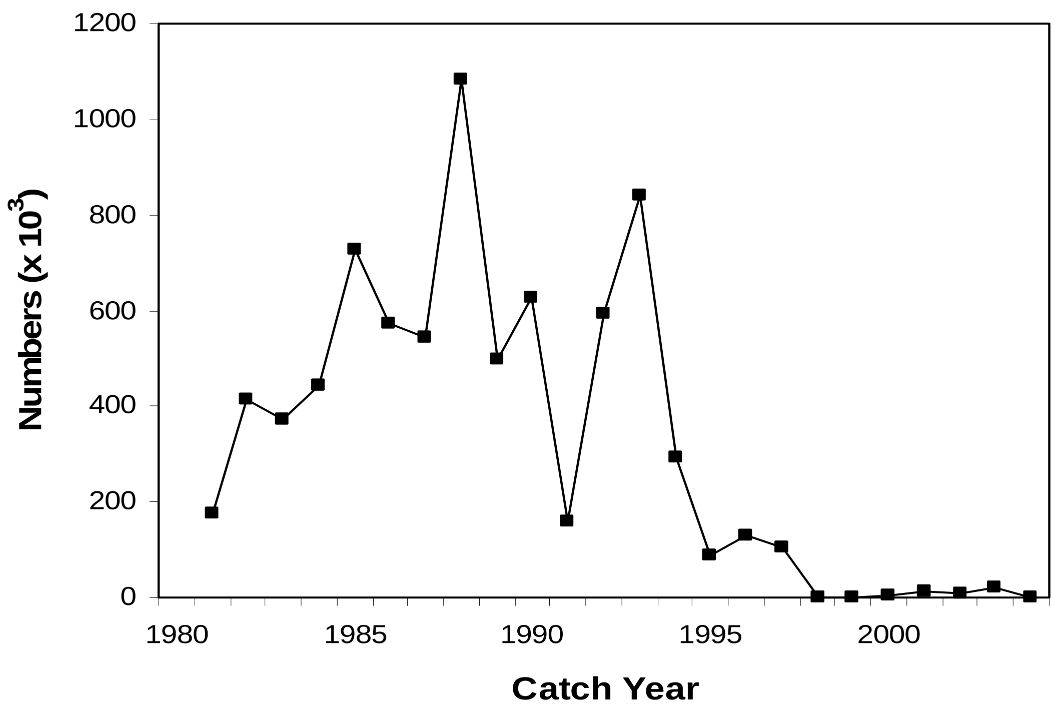

Fig. 2. Total returns (catch and escapement) and escapement anomaly of pink salmon to the Fraser River 1956 – 2003.

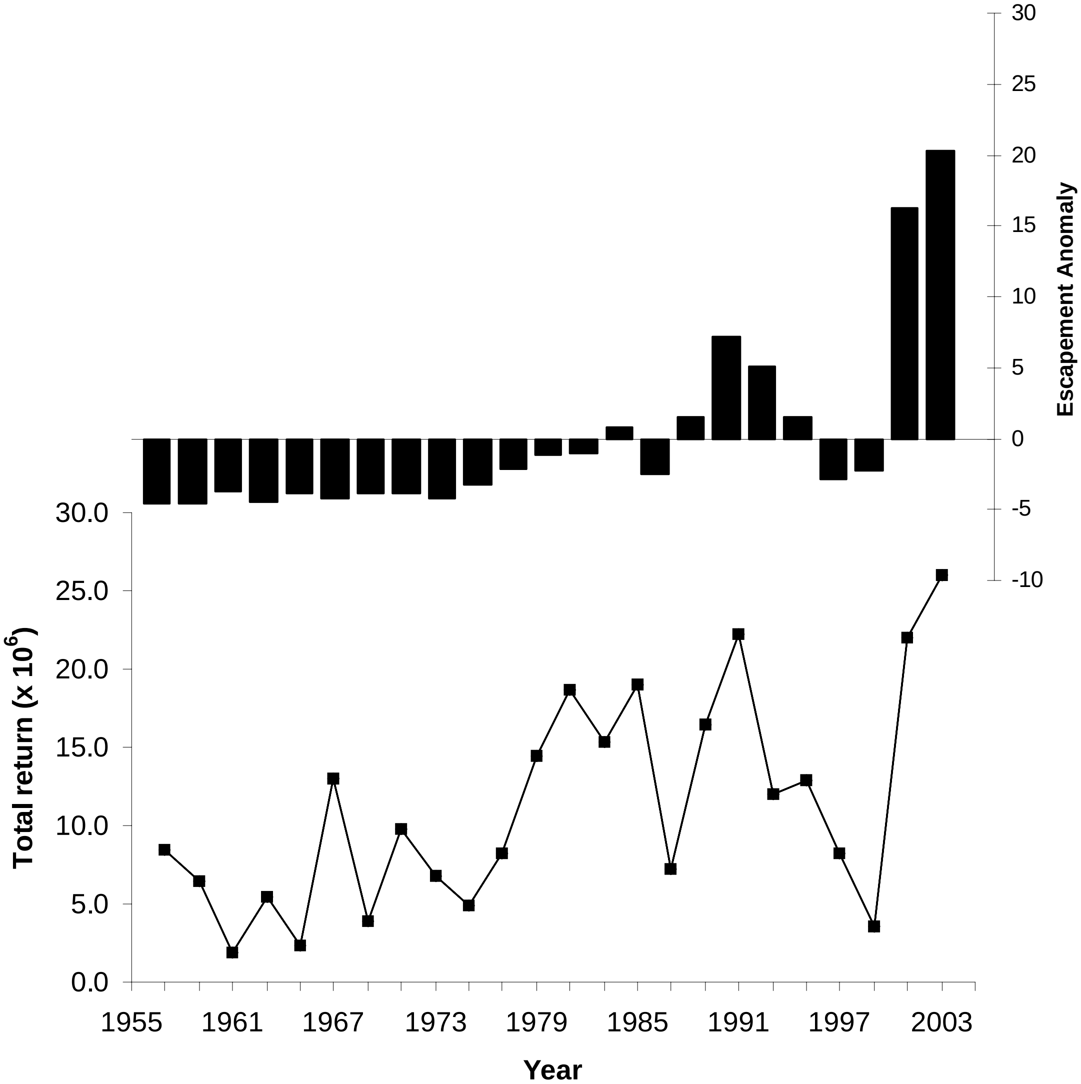

Fig. 3A. Percentage of hatchery-reared coho salmon in the Strait of Georgia from 1975 to 2006. The average annual values from 1974 to 1992 are calculated from sport and commercial catches and adjusted to year to sea. The values from 1997 to 2006 are calculated from tagging percentages in the trawl surveys conducted in July of each year.

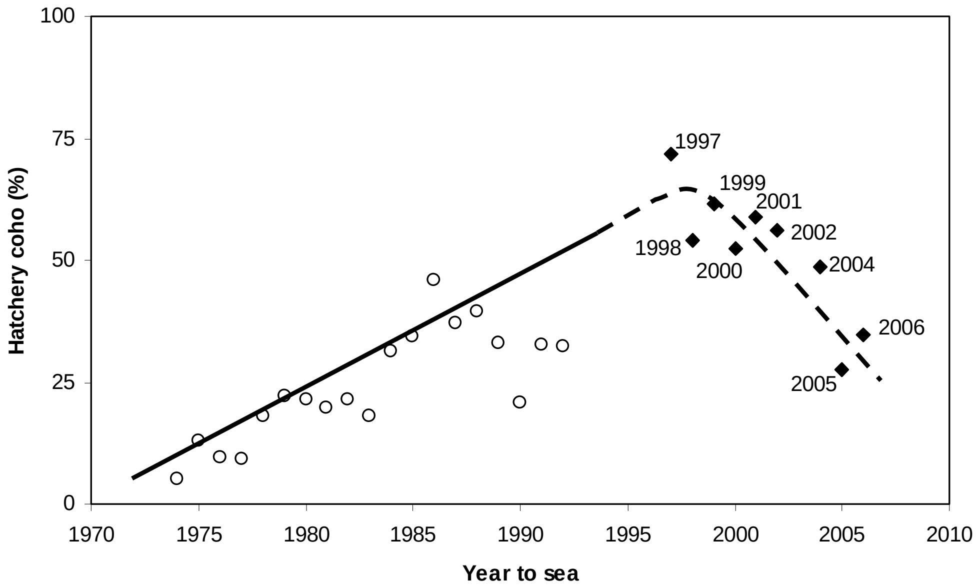

Fig. 3B. Percentage of hatchery-reared coho salmon in the Strait of Georgia from 1975 to 2006. The average annual values from 1974 to 1992 are calculated from sport and commercial catches and adjusted to year to sea. The values from 1997 to 2006 are calculated from tagging percentages in the trawl surveys conducted in September of each year.

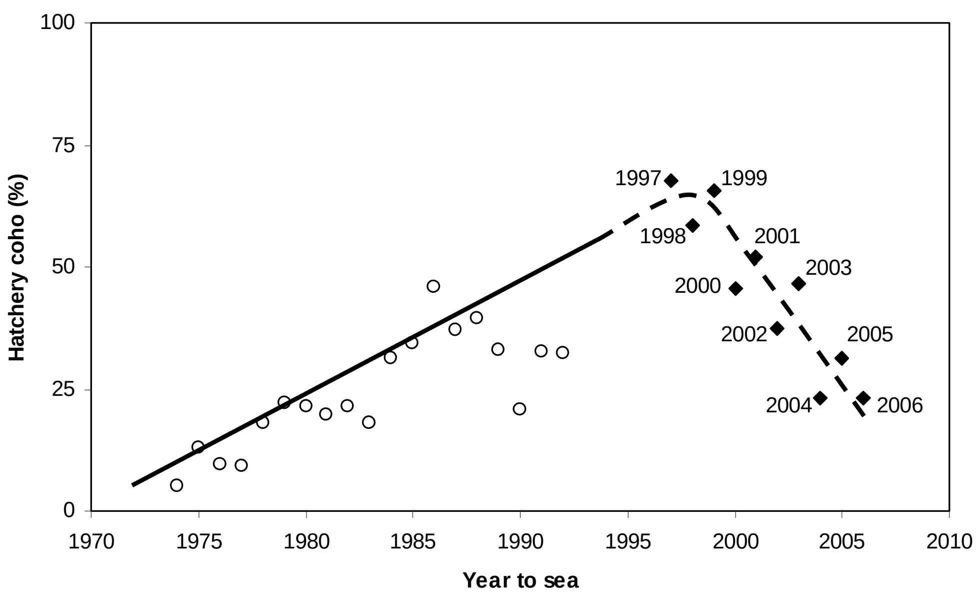

Fig. 4A. Estimated abundance of hatchery and wild juvenile coho in the Strait of Georgia July 1997 to 2006.

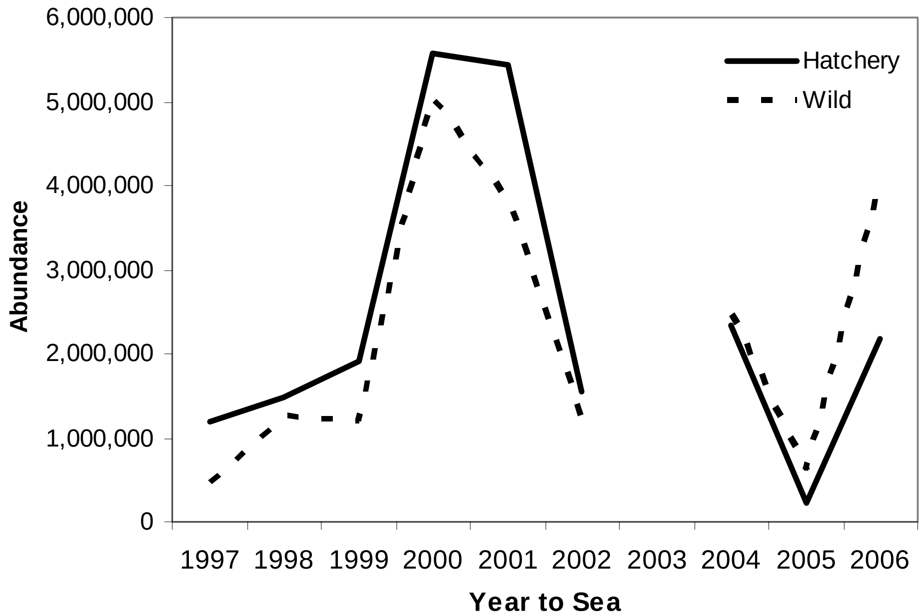

Fig. 4B. Estimated abundance of hatchery and wild juvenile coho in the Strait of Georgia September 1997 to 2005.

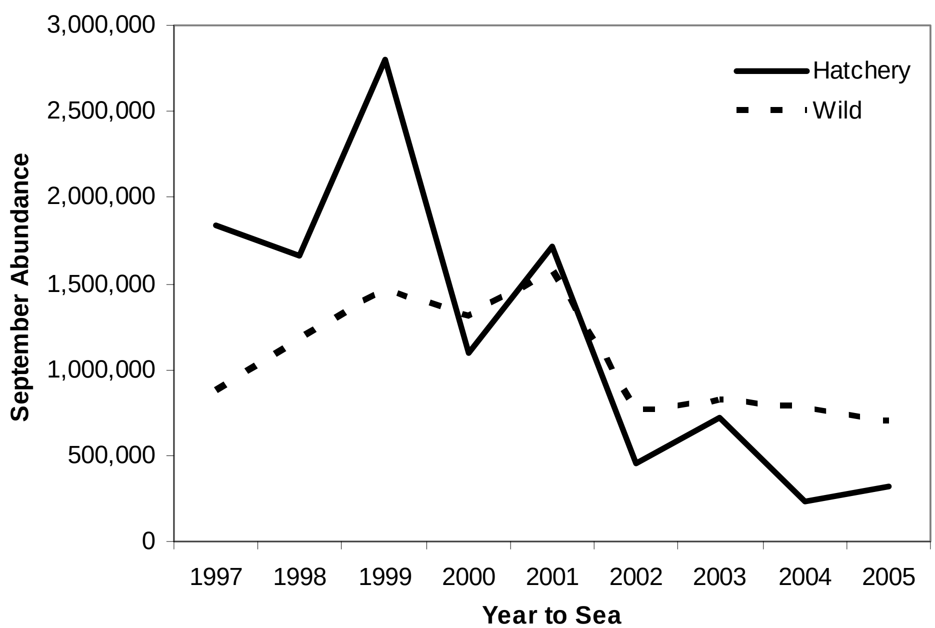

Fig. 5. Number of hatchery coho salmon released into the Strait of Georgia 1970-2004.

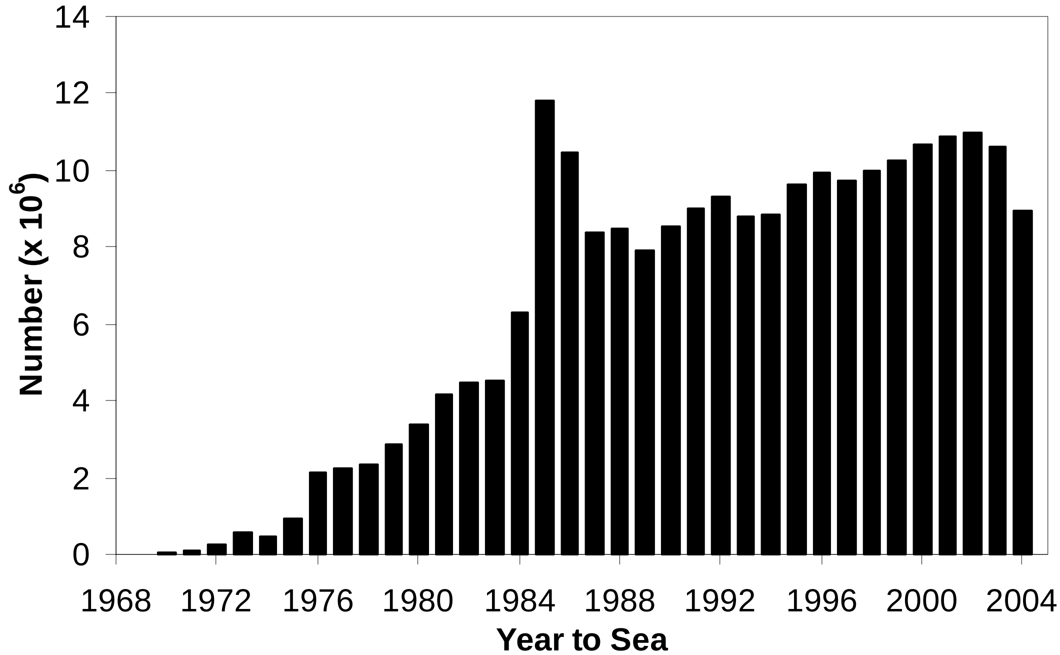

Fig. 6. Average date when 50% of the coho salmon were released from hatcheries in the Strait of Georgia.

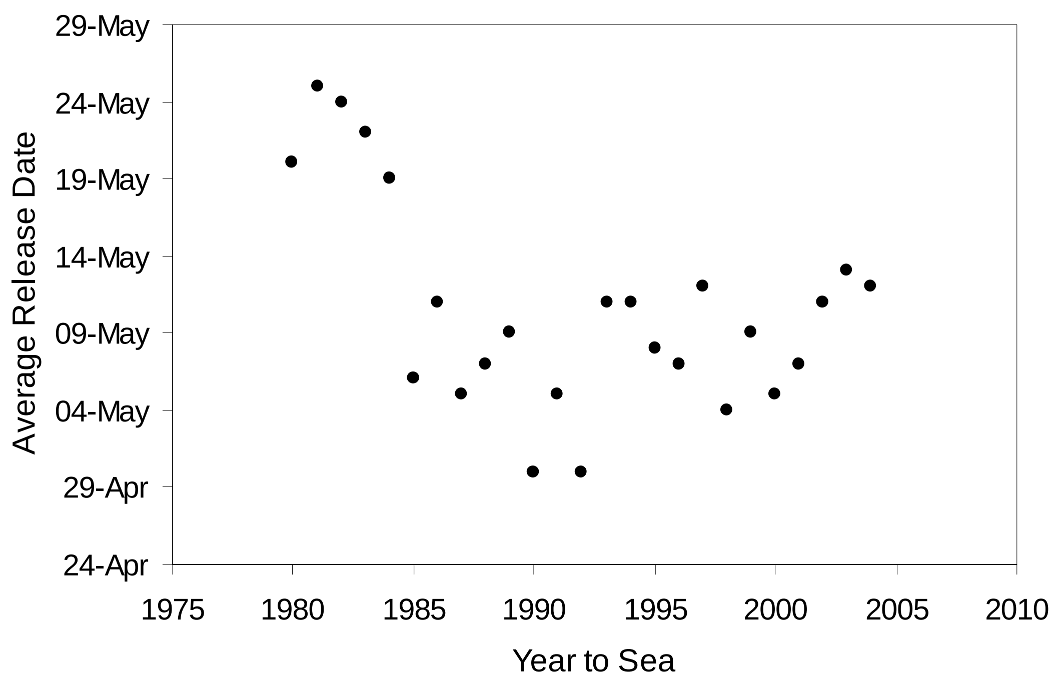

Fig. 7. Total returns (catch and escapement) of sockeye salmon to the Fraser River 1959-2005.

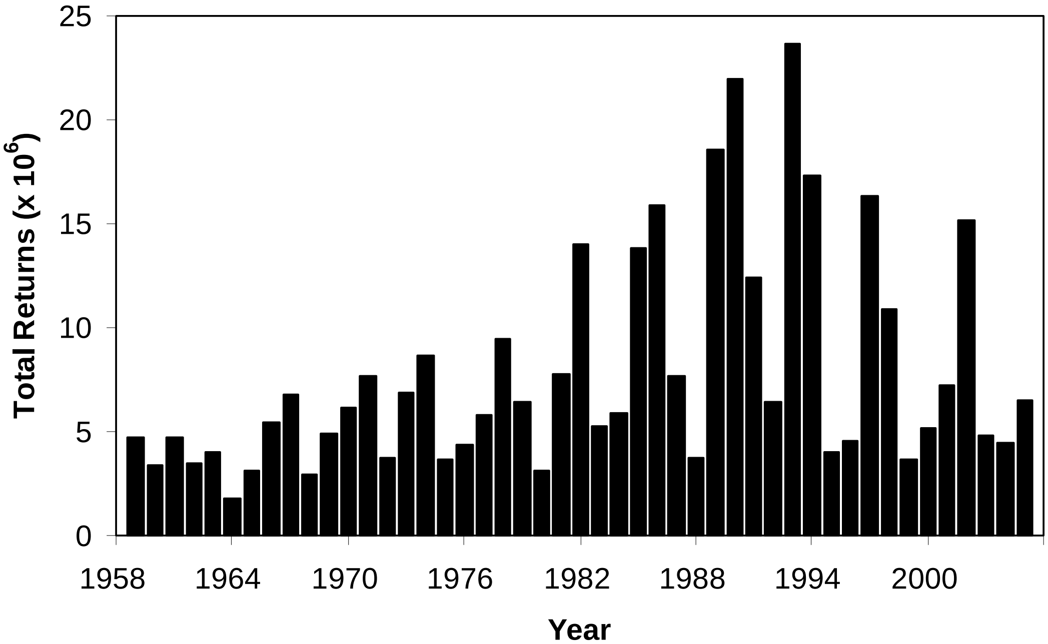

Fig. 8. Escapement index of chum salmon to the Strait of Georgia 1959 -2002. The index in constructed using escapements to 13 rivers consistently surveyed and represents approximately 69% of the escapement recorded over this period.

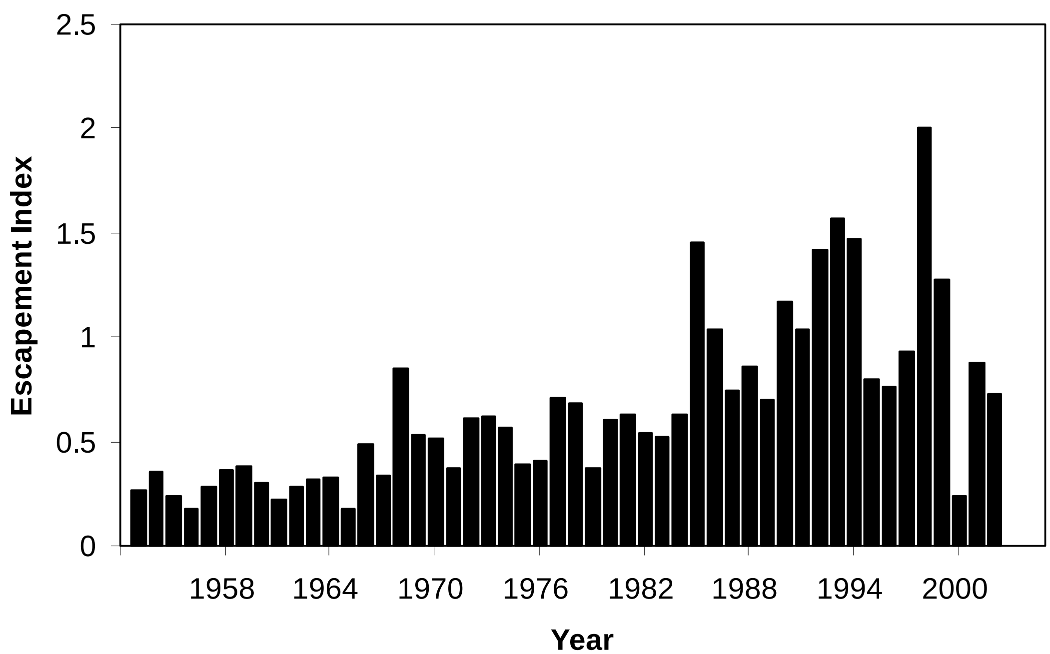

Fig. 9. Estimated abundance of chinook and coho (dashed line) and pink, chum and sockeye (solid line) salmon juveniles during 1967-1976 and 1993-2003.

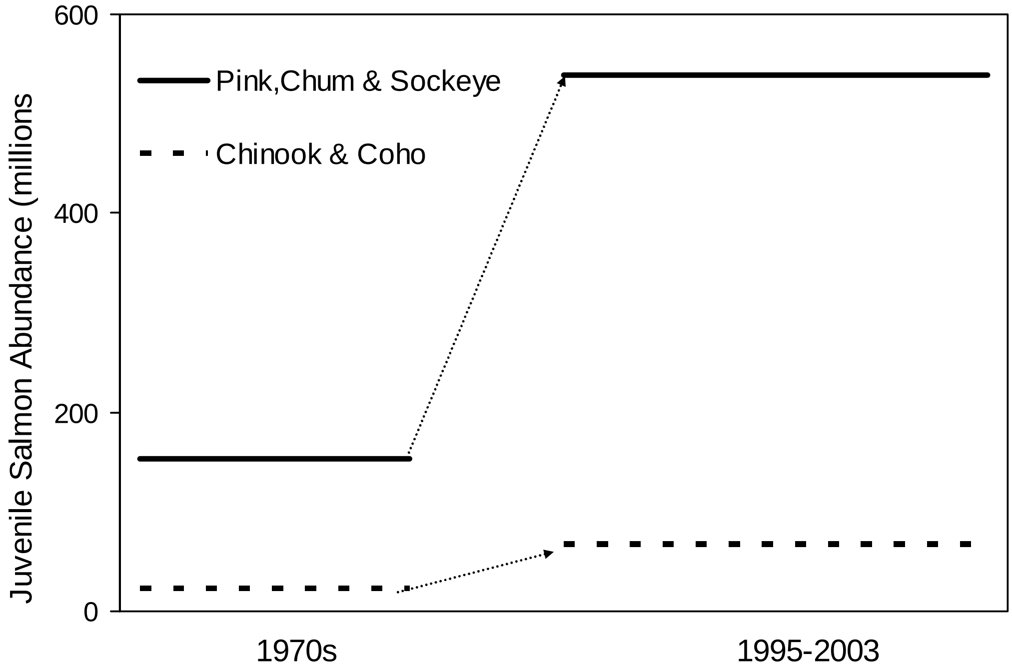

Fig. 10. Estimated marine survival of coho salmon (brood year 1971 – 2002).

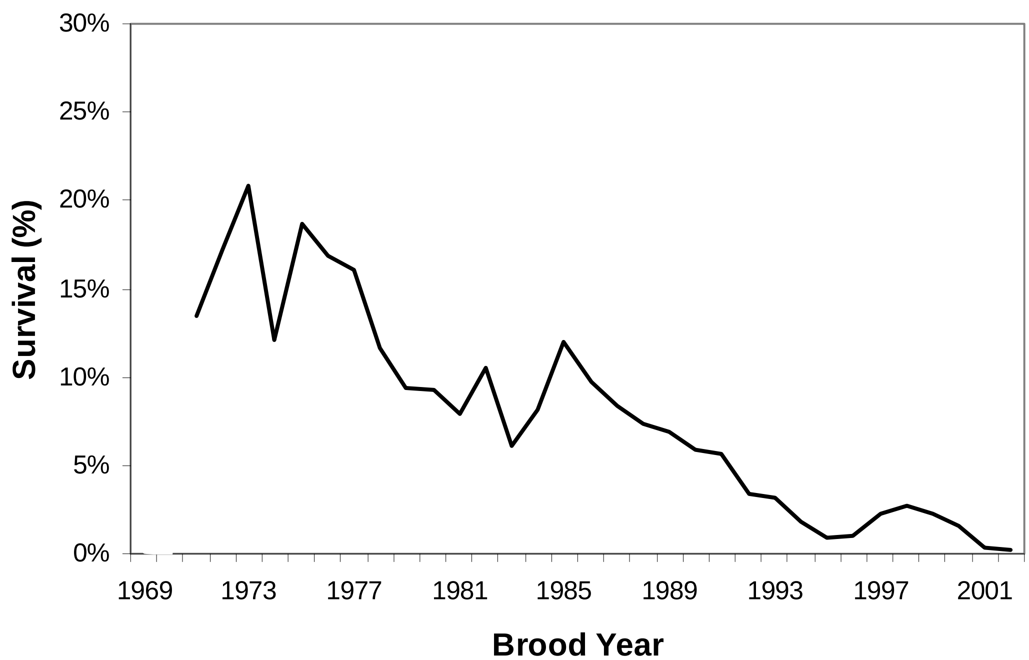

Table 1. Estimated abundance of juvenile coho salmon in the Strait of Georgia during July 1997 to 2006.

Year to Sea	Abundance	Lower Interval – Upper Interval
1997	1,650,000	350,000 – 2,970,000
1998	2,820,000	1,510,000 – 3,350,000
1999	3,420,000	2,220,000 – 4,570,000
2000	10,960,000	6,600,000 – 15,840,000
2001	9,270,000	6,240,000 – 12,680,000
2002	2,750,000	2,130,000 – 3,870,000
2003	NO SURVEY	No survey
2004	4,790,000	2,836,000 – 5,156,000
2005	820,000	535,000 – 1,105,000
2006	6,150,000	*

* not yet available