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# Ocean Changes in the Strait of Georgia Indicate a Need to Link Hatchery Programs, Fishing Strategies and Early Marine Studies of Ocean Carrying Capacity into an Ecosystem Approach to Manage Coho Salmon

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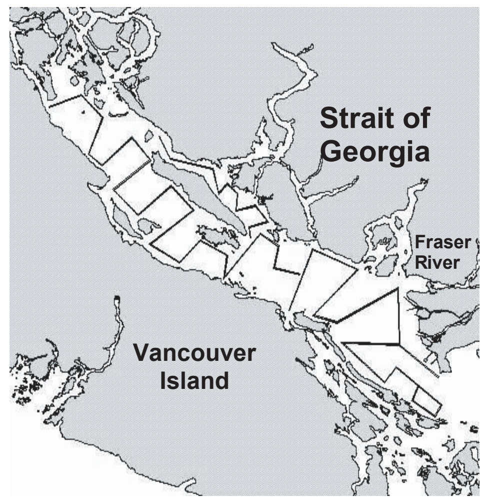
We studied the factors that affected the early marine survival of juvenile Pacific salmon in the Strait of Georgia since 1997 using a standard midwater trawl (Beamish and Folkes 1998) that is fished throughout the water column at 15 m intervals. A standard survey is shown in Fig. 1. The Strait of Georgia is perhaps the most important juvenile Pacific salmon rearing area off the west coast of Canada. Historically, about one third of all the salmon in the commercial catch originated from rivers around the Strait of Georgia and reared as juveniles in the strait. The Fraser River is the major river producing these salmon that enter the Strait of Georgia. The salmon from the Fraser River have traditionally been fished by Canada and the United States requiring a treaty and a joint management agency. The original commission that is now the Pacific Salmon Commission was established in 1937. The Commission has been responsible for maintaining accurate catch and escapement records for sockeye salmon and, up to a few years ago, for pink salmon. We used this information and records from the Department of Fisheries and Oceans to estimate the average annual number of juvenile Pacific salmon that reared in the Strait of Georgia from 1970 to 1979 and from 1996 to 2004. We estimated that there has been an increase in the numbers of juvenile pink, chum and sockeye salmon in recent years, whereas the numbers of juvenile coho and chinook salmon has not increased. The result has been a doubling of the dominance of pink, chum and sockeye over coho and chinook salmon. An example of the increased abundance of pink, chum and sockeye salmon is shown in the returns of adult pink salmon to the Fraser River (Fig. 2).

**Fig. 1**. The Strait of Georgia showing the standard survey track.




The reason for the switching of dominance appears to be related to changes in the Strait of Georgia in the timing of the initial spring production. Yin et al. (1997) related the timing of the beginning of production to the beginning of the freshet in the Fraser River in April. In Fig. 3, it is apparent that in recent years there has been a

**Fig. 2.** Production of pink salmon in the Fraser River in odd-numbered years only. Virtually all adults return to the Fraser River in odd-numbered years.

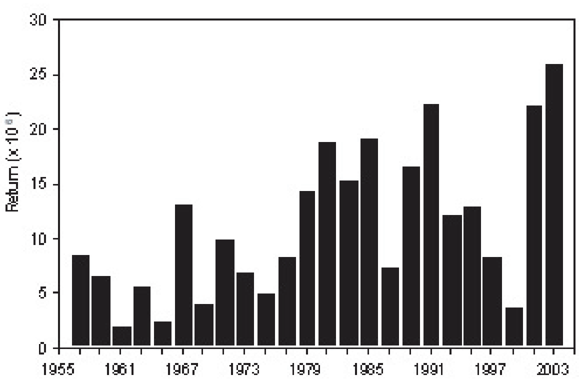
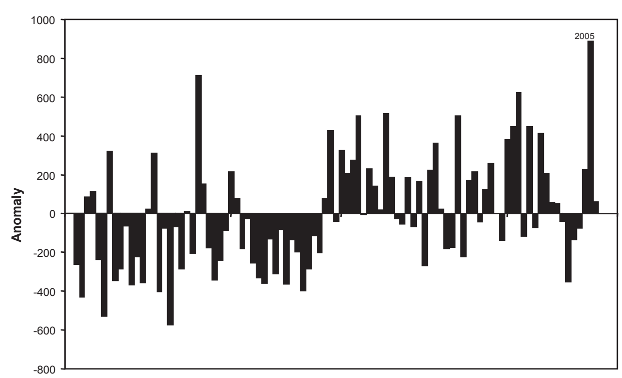



**Fig. 3.** Anomaly of the flow in the Fraser River from January to April. Note the anomaly in 2005 which is the largest in the data series.

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trend to increased earlier flows, suggesting an earlier timing of the initial plankton bloom. A dramatic example of this relationship occurred in 2005. The amount of flow in April was the largest in ever recorded (Fig. 3), and evidence from other studies indicated an exceptionally early spring bloom (S. Allen, University of British Columbia, Vancouver, BC V6T 1Z4, Canada, personal communication). Our surveys in July found that abundances of juvenile coho and chinook salmon were the lowest in the study, but the abundances of chum salmon were the highest. Clearly, the chum salmon that entered the strait first and early in the year had exceptionally good survival, while coho and chinook that entered later in the year had exceptionally poor survival.

Ecosystem management can be considered in a number of ways. We propose that ecosystem management is management that appreciates the dynamic relationships among the key species and their environment. This means that managing coho salmon requires an understanding of the natural processes that affect coho production in the ocean. Our studies suggest that natural changes in the Strait of Georgia probably have advanced the date of plankton blooms which improved the production of species such as chum and pink salmon that entered the ocean early. However, many coho salmon that enter the Strait of Georgia are not really wild as they are produced in hatcheries (Fig. 4; Sweeting et al. 2003). We also know that most of these coho salmon are released into the strait about mid-May and that these release dates have remained fairly constant for about 25 years (Fig. 5). We know that since the mid-1980s there has been a rather constant release of around 10 million coho salmon from hatcheries and a declining marine survival of coho that in recent years is about one percent (Fig. 6).

A definition of a wild salmon used by Fisheries and Oceans Canada (Anon. 2005) is a salmon that spent their entire life cycle in the wild and originated from parents that were also produced by natural spawning and who continuously lived in the wild. Thus, on one hand, hatchery-reared coho salmon may not able to adapt naturally to the ocean habitat changes to maintain historic high marine survivals; but on the other hand, their release times from hatcheries can be artificially manipulated to adapt to the changing timing of prey availability. As climate continues to change, it is apparent that future management of coho has to be flexible, adaptive and linked to physical

**Fig. 4.** Percentage of coho salmon produced in hatcheries (modified from Sweeting et al. 2003).

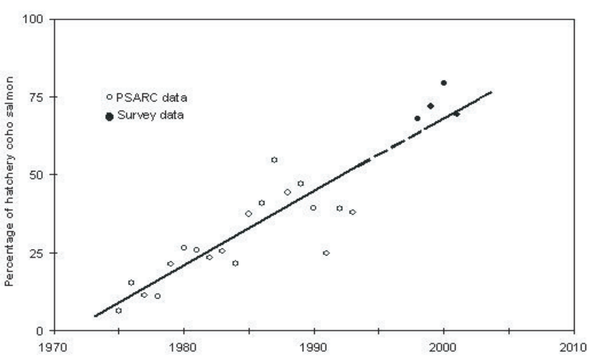



**Fig. 5.** Average date that 50% of all coho salmon produced in hatcheries were released into the Strait of Georgia.

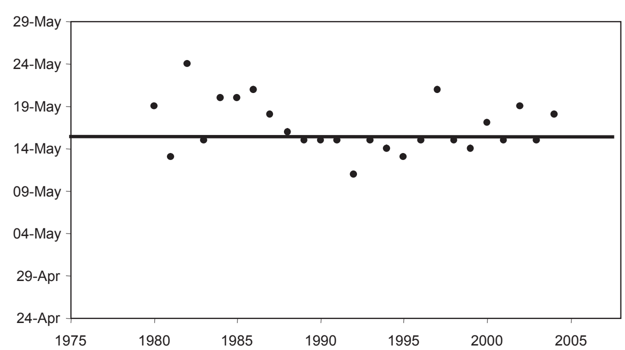



**Fig. 6.** Strait of Georgia coho salmon smolt production from hatcheries and marine survivals for brood years 1976 to 2001 (year of ocean entry is two years later in 1978 to 2003).

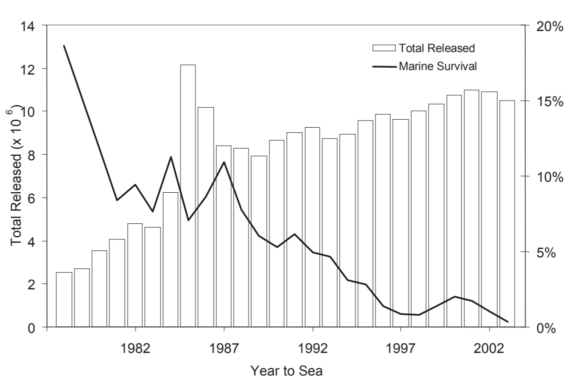
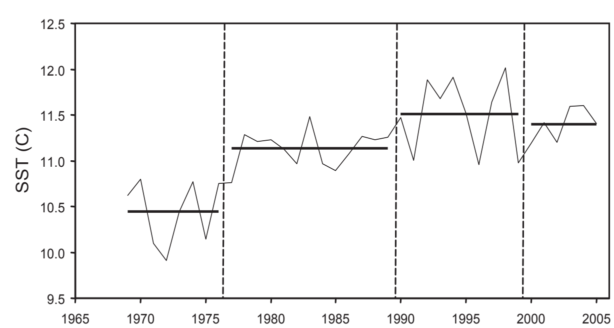



**Fig. 7.** Mean sea surface temperature in the central Strait of Georgia from 1969 to 2005. Vertical dashed lines represent regime shift years and horizontal solid lines indicate the average sea surface temperature determined at the Nanoose site (Beamish et al. 2004).



and biological conditions within the Strait of Georgia. We know that the Strait of Georgia is warming (Fig. 7) and that the warming occurs in trends that match regimes and regime shifts (Beamish et al. 2004). The physical and biological processes that regulate the timing and amount of primary production will be affected by this warming and associated changes such as river flow and atmospheric wind direction and intensity. The impacts on factors such warming, regional winds, and Fraser River flows are unlikely to be linear, as these conditions respond in trends or regimes, and shift to new states quickly. Thus, future changes may follow a long-term trend, but these changes would occur on a decadal scale.

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