Final Report to PSC Southern Fund for project "Mechanisms regulating the production of coho, Chinook, and steelhead in the Strait of Georgia and Puget Sound"

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Background

During the 1990s the production of coho and Chinook salmon originating from the Strait of Georgia and Puget Sound declined. This decline occurred even though hatcheries released millions of juvenile coho and Chinook salmon into these regions. The decline in salmon impacted the recreational, commercial and First Nations fisheries (Figure 1) as well as the tourism industry in British Columbia.

In 1998 there was a regime shift (King 2005) and the productivity of many species in the Strait of Georgia shifted. This included an increase in the marine survival and production of some salmon species, such as pink salmon. The total return (catch and escapement) of pink salmon to the Fraser River in 2001 and 2003 were some of the highest observed in a 50 year period. Coho and Chinook salmon, the species of most interest to the recreational fishing industry, showed a slight increase in production for the 1998 and 1999 brood years. This improvement continued for some regions of Puget Sound, however, did not persist in the Strait of Georgia where the marine survival returned to the low levels observed during the late 1990s (Figure 2).

The objective of this study was to improve our understanding of the mechanisms regulating the marine survival of salmon species in the Strait of Georgia and Puget Sound and why the marine survival in these two basins and between salmon species varied. In addition, the study would provide recommendations on management actions that may help improve coho and Chinook production in the Strait of Georgia and early forecasting methods to provide managers with an important tool for developing fishery plans.

This report provides the approach and a general summary of the findings of the project. Data used in this study are available upon request to R.J. Beamish. Detailed methods and results of this study are being published in the primary literature. A draft of the first paper, Changes in the trend of the percentages of hatchery and wild coho salmon in the Strait of Georgia, is attached as Appendix A

Coho

In this project we considered changes in survival and behaviour of the coho population from the Strait of Georgia and Puget Sound over the past 2-3 decades. In addition, we examined other biological and physical changes that may have occurred synchronously with changes in the coho population. Specific attention was given to the regime shift in 1998 and the years directly following this shift, as we knew it was a period of change and may be a link to identifying the mechanisms regulating coho abundance and survival. The quality of the data available for this study varied. Some data sets (eg. Strait of Georgia temperature, Fraser River flow, hatchery production) are available for all time periods studied (years and seasons) and are of good quality. Other data (eg. estuarine circulation patterns, timing of spring bloom) are generalized from fewer observations and there is not data available for all time periods.

Survey data

Juvenile salmon surveys have been conducted in both the Strait of Georgia and Puget Sound since 1997. These surveys are generally conducted in July and September in the Strait of Georgia and Puget Sound (Table 1) using the methods described in Beamish and Folkes (1998) and Sweeting et al. 2003. In this study we use the catch of salmon standardized to one hour (CPUE) to represent abundance. In general, juvenile coho and Chinook salmon are more abundant in Puget Sound than in the Strait of Georgia in July (Table 2). Chum salmon were also more abundant with the exception of 2005 (Table 2). Sockeye salmon are rarely caught in Puget Sound and therefore abundance estimates are not calculated. In addition to differences in abundance of these species between basins, the behaviour and movement of the juvenile salmon is different. The abundance of coho salmon in Puget Sound decreases significantly between July and September indicating that they have left this region. This is supported by the recovery of coded wire tags, originating from Puget Sound, in Juan de Fuca Strait, the Strait of Georgia, and the west coast of Vancouver Island. In most years, the CPUE of coho in the Strait of Georgia remains similar to July and few tags are recovered in other regions, suggesting that large numbers of coho continue to rear in the Strait of Georgia into September (Table 2).

The average size of the coho and Chinook caught in the Strait of Georgia was not consistently larger or smaller than those from Puget Sound in any given year (Table 3) and the differences in size were not statistically different. The average size of chum salmon from the Strait of Georgia was consistently smaller than chum salmon caught in Puget Sound.

Diet information was summarized for juvenile chinook and coho salmon in the Strait of Georgia and in Puget Sound. There is a diet overlap among coho, pink and chum salmon (Figure 3). The diet overlap is important because we were able to show that marine survival is linked to how fast coho grow in the first few months in the ocean. We propose that competition for food may reduce growth sufficiently and delay lipid storage which increases overwinter mortality. We did not test this idea, but a comparison of lipid levels in September with back calculated growth using otoliths should show that fish with the highest lipid levels had the smallest amount of growth between mid July and mid September. Thus the diet overlap among juvenile Pacific salmon is a serious consideration for hatchery management as it appears to affect the carrying capacity of the Strait of Georgia for Pacific salmon. This means that the production of chum salmon in hatcheries or the large escapement of pink salmon, could affect the carrying capacity of the Strait of Georgia for coho and Chinook salmon, particularly when prey abundance is low.

Hatchery data

The production of hatchery reared salmon in the Strait of Georgia began in the early 1970s. The numbers of coho salmon produced in hatcheries increased steadily until mid-1980s. Releases remained at about 9 million fish between 1988 and 2002. In the past 5 years, production has declined slightly but remains above 6 million. Originally, about 7% of the hatchery reared coho had a coded wire tag and were distinguishable by the removal of their adipose fin. This mark recapture program provided valuable information on the survival, distribution and stock origin of hatchery coho. In 1997, with the introduction of mark only fisheries for Strait of Georgia coho, the program changed. Over 75% of coho originating from the Strait of Georgia had the adipose fin removed although only a small number of these carried the coded wire tag. The combination of reduced catch of coho and the difficulty in recovering CWT's from fish that were captured, reduced the information that was available on distribution and stock origin of Strait of Georgia and Puget Sound coho salmon from sport and commercial fisheries. However, the examination of all coho caught in our juvenile surveys for the presence of CWT's provided early marine information on the distribution, survival and stock composition of these fish. Coho salmon released in the Strait of Georgia were never captured in the trawl surveys in Puget Sound. However, about 5-18% of the CWT's recovered in the Strait of Georgia in July and September, originated from Puget Sound (Figure 4). In addition, the adipose clipping of over 75% of the hatchery coho provided additional information on the survival and distribution of wild coho salmon compared to hatchery coho. Due to the high clipping percent, we assumed that all fish with the adipose fin were wild and all with the adipose fin removed were hatchery. In this analysis, the survival of unclipped or wild coho is greater than clipped or hatchery coho (Figure 5).

From the beginning of the hatchery program in the 1970s, there was a steady increase in the percentage of hatchery coho in the Strait of Georgia. By 2001 over 70% of all coho in the Strait of Georgia originated from hatcheries (Sweeting et al. 2003). In recent years this increasing trend has shifted and there is now a trend of reduced hatchery coho observed in the Strait of Georgia in both July and September of their first marine year (Figure 6). In July of 2006, hatchery coho represented approximately 30% of all coho in the Strait of Georgia. The relatively constant release of coho from hatcheries in this region, suggest that this decrease in hatchery coho is a result of improved survival of wild coho and reduced survival of hatchery coho salmon since the 1998 regime shift. This is evident in the estimated abundance of hatchery and wild coho in the Strait of Georgia in July and September (Figure 7). In the 1990s, the abundance of hatchery coho was greater than wild coho. However, in the past few years this trend has reversed and there are now more wild coho salmon in the Strait of Georgia in both July and September than hatchery coho.

Coho salmon from hatcheries in the Strait of Georgia are released at specific times to achieve maximum survival. This timing is based on size and time of release studies conducted in the 1970s (Bilton et al. 1982a, 1982b). As a result, release timing has remained relatively constant over the past 25 years with an average 50% release date of May 17th (Figure 8). In comparison, wild coho and all fry, can adjust their ocean water entry timing depending on environmental conditions. The release timing of hatchery coho in Puget Sound has not been constant but has had a trend towards earlier releases in recent years. The releases have also occurred earlier than in the Strait of Georgia (Figure 8).

The mean size of hatchery produced coho released into the Strait of Georgia and Puget Sound also varied. Although the mean size within each basin has remained relatively constant, the mean size of coho released in Puget Sound is about 7 grams larger than those released into the Strait of Georgia (Figure 9). This could have implications on the variation in survival in these two basins as larger coho generally have greater survival than smaller coho (Figure 5).

Previous studies by Beamish and Mahnken (2001) and Beamish et al. (2004) indicated that the growth of coho during their first marine summer was important in determining marine survival. In this study we compared the growth of hatchery and wild coho. Relationships between growth, survival and abundance for wild coho salmon were evident earlier in the year than for hatchery coho salmon. This suggested that wild coho salmon may be feeding and growing differently or earlier than hatchery coho salmon and this earlier feeding may be improving the growth and survival of wild coho salmon. This was apparent even though wild coho salmon caught in our surveys were consistently smaller than hatchery coho salmon. Therefore, it is not the absolute size of the juvenile coho that is critical but the salmon that can grow faster during the early marine period and store more lipids for improved survival over the winter months (Post and Parkinson 2001, Beamish and Mahnken 2001).

Comparisons between hatchery and wild coho suggested that there may be a change in the timing of food production for juvenile salmon in the Strait of Georgia. Changes in the timing of the early plankton production in the Strait of Georgia may be effected by several factors. Nutrients in the Strait of Georgia are primarily provided by estuarine circulation driven by the Fraser River. A change in timing of the spring freshet or a change in volume of water entering the strait in the winter or spring may impact early production. In addition, a reduction in winds during the winter months may increase the stability of the surface layer resulting in earlier production. The specific mechanisms to shift the spring production have not yet been identified. However, improvements in survival in other marine fish that are present in the surface waters of the strait earlier in the year indicate that changes during these winter/spring months are present. This includes good or improved survival of pink, chum and sockeye salmon and Pacific herring. These juvenile salmon enter the strait earlier in March and April. The number of juvenile pink, chum and sockeye salmon in the strait has increased and there has been a trend for them not to leave the strait as quickly as had been reported in the 1970s (Healey 1980) but to remain in large numbers through July and even September of their first marine year. Pacific herring spawn in late winter and begin feeding in early March. The abundance of Strait of Georgia herring stocks is strong suggesting that conditions for the juveniles are good. These changes are also linked to the regime shift in 1998.

The results of this study confirmed that a strong linkage exists between ocean climate and fish productivity. Decreases in the abundance and marine survival of Strait of Georgia coho salmon occurred concurrent with regime shifts. In addition, the presence of hatchery released coho salmon provided an opportunity to identify some of the possible mechanisms associated with these decreases. Although there has been relatively constant hatchery releases since the early 1990s, the percentage of hatchery coho present in the Strait of Georgia has shifted from an increasing trend in the 1990s to a decreasing trend following the 1998 regime shift (Figure 6). This decrease in the percentage of hatchery coho salmon appears to result from a decrease in the marine survival associated with a constant average release time from hatcheries and from a shift to earlier prey production in the Strait of Georgia. In addition, in the last few years this change may be associated with recent reductions in hatchery production and with an increase in the abundance of juvenile wild coho salmon (Figure 7). The survival and ocean entry timing of wild coho salmon are not as easily measured, however, the wild coho may have adjusted to the change in timing of prey production and may be entering the Strait of Georgia earlier resulting in improved marine survival. It is unfortunate that there is not better information on the ocean entry times and marine survival of coho salmon. There is evidence from studies at Black Creek that there has been a trend to earlier ocean entry times, which supports our interpretation. However, this is only one population. Survival estimates for coho salmon are based on CWT information from hatchery coho salmon. The increase in wild coho abundance in recent years is an indication that their marine survival is increasing while hatchery coho salmon survival is decreasing (under the current strategy for hatchery coho). This would indicate that the carrying capacity for wild coho salmon may differ from hatchery coho salmon. Certainly, this study shows that marine survival estimates for hatchery coho need to be applied cautiously to wild coho salmon as hatchery coho are not able to adjust their ocean entry times naturally. Thus the freshwater survival of wild coho may have also improved although we could not measure this directly.

The changing trend in the percentages of hatchery and wild coho salmon indicates that the management of hatchery coho salmon needs to consider the impact of changing climate and ocean conditions. Release times and probably release sizes should be more experimental by relying on selected biological and physical indicators within the Strait of Georgia ecosystem. Based on early results from this study, Quinsam and Inch Creek hatcheries have begin experimenting with release timing. They should have results over the next few years. In addition, this study has highlighted the complexity of the ocean phase of coho salmon and the differences between the patterns of growth and survival of hatchery and wild coho salmon. It is recommended that it may be important to manage hatchery and wild coho salmon separately until more is known about the mechanism causing the different responses.

Chinook salmon

Our focus for Chinook salmon was to compare the CWT recaptures over the past 10 years. The preliminary results were presented at the recent Strait of Georgia, Puget Sound symposium. We attached tables showing which hatcheries consistently had higher than expected CWT recapture rates (Table 4). We used the CWT analysis to show that some populations such as Cowichan may have up to 80% mortality of juveniles in the first few months in the ocean. However, we need a separate study for juvenile Chinook salmon to determine why early marine mortality is so high. We will propose this study again this fall.

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Table 1. Date of survey, number of sets, of coho salmon for July (A) and September (B) surveys in the Strait of Georgia and Puget Sound.

YEAR	Strait of Georgia		Puget Sound	
	Date	Number of sets	Date	Number of sets
1997	June 17 - 20, July 06 -11	53	July 9-10	14
1998	June 30 - July 09	60	July 10-11	10
1999	June 30 – July 08	78	July 16	8
2000	July 11 – July 20	72	July 21	3
2001	July 07 – July 15	76	July 16	9
2002	July 02 – July 11	86	July 13-14	13
2003	NO SURVEY	-		
2004	July 04 – July 13	91	July 14-16	22
2005	July 14 – July 21	76	July 22-23	16
2006	July 09 – July 20	65	July 21-22	15
Total		657		110

YEAR	Strait of Georgia		Puget Sound	
	Date	Number of sets	Date	Number of sets
1997	Sept 08 - 22, 25 - 27	110	Sept 23-24	14
1998	Sept 08–10,12-16,23-24	78	Sept 22	9
1999	Aug 31 – Sept 08	73	Sept 15	8
2000	Sept 09-10, 14-24, Oct 01	82	Sept 25-26	15
2001	Sept 16 - 27	87	Sept 15-16	17
2002	Sept 20 - 28	74	Sept 29-30	16
2003	Sept 13 - 22	77	-	0
2004	Oct 07 – 18	64	Oct 15-16	16
2005	Sept 14 – 21, 28 – 29	63	Sept 22-23	17
2006	Sep 08 – 21, Oct 01	59	Sept 22-23	14
Total		767		126

Table 2. CPUE of juvenile salmon in the Strait of Georgia and Puget Sound in July and September, 1997-2006.

July	Strait of Georgia					Puget Sound			
Year	Coho	Chinook	Chum	Pink	Sockeye	Coho	Chinook	Chum	Pink
1997	18.6	46.6	39.1	0.8	105.7	288.9	542.1	191.3	0.6
1998	41.1	48.6	216.1	92.5	20.9	115.2	176.2	227.0	105.3
1999	41.7	38.9	125.1	0.3	22.2	289.2	393.6	297.0	0.0
2000	126.1	69.4	437.5	127.0	9.	476.0	1656.0	150.0	172.0
2001	114.1	59.5	217.8	1.5	32.8	177.5	263.5	224.3	29.0
2002	43.1	42.8	30.5	84.8	6.2	392.4	474.7	254.3	226.9
2003	-								
2004	60.0	77.2	276.9	128.9	63.3	98.6	539.0	4571.5	2967.5
2005	10.9	18.1	453.7	1.0	11.9	175.6	257.3	433.3	1.8
2006	102.9	86.9	139.6	110.8	5.9	7.6	46.9	140.7	392.4

September	Strait of Georgia		Puget Sound	
Year	Coho	Chinook	Coho	Chinook
1997	40.1	52.8	10.2	239.6
1998	38.4	36.3	7.8	119.8
1999	55.3	29.9	41.8	331.0
2000	32.4	24.2	7.0	142.2
2001	46.6	22.5	11.7	125.2
2002	17.0	37.3	4.5	92.8
2003	21.9	30.5		
2004	11.0	21.2	8.2	120.0
2005	16.4	89.7	19.2	297.0
2006	21.3	41.7	26.6	233.4

Table 3. The average length (SD) and sample size of coho, chinook and chum salmon sampled in the Strait of Georgia and Puget Sound in July 1997 to 2006.

	COHO		CHINOOK		CHUM	
YEAR	Strait of Georgia	Puget Sound	Strait of Georgia	Puget Sound	Strait of Georgia	Puget Sound
1997	159.2 (22.5) (N = 520)	208.0 (23.9) (N = 846)	140.3 (33.8) (N = 1585)	130.7 (23.9) (N = 1405)	121.5 (25.6) (N = 907)	131.9 (17.1) (N = 504)
1998	172.8 (23.3) (N = 1219)	166.9 (19.0) (N = 350)	120.8 (36.9) (N = 1411)	124.1 (29.5) (N = 157)	122.9 (15.0) (N = 1206)	133.0 (16.4) (N = 348)
1999	167.6 (22.3) (N = 1639)	196.5 (23.1) (N = 160)	139.0 (37.4) (N = 1664)	131.4 (16.8) (N = 643)	115.8 (19.4) (N = 1227)	139.5 (16.5) (N = 325)
2000	199.8 (23.4) (N = 3360)	193.5 (21.6) (N = 198)	143.7 (36.9) (N = 1994)	143.4 (22.7) (N = 289)	127.9 (18.0) (N = 2609)	142.7 (17.5) (N = 20)
2001	184.5 (21.0) (N = 2957)	196.2 (25.1) (N = 418)	146.0 (32.3) (N = 2211)	127.7 (21.9) (N = 557)	130.4 (17.5) (N = 2192)	141.3 (20.3) (N = 189)
2002	168.6 (22.7) (N = 1887)	185.7 (23.8) (N = 567)	136.2 (28.8) (N = 1984)	117.6 (20.9) (N = 1089)	114.6 (15.2) (N = 1067)	122.3 (16.1) (N = 213)
2003	-	-	-	-	-	-
2004	178.9 (28.2) (N = 2257)	179.7 (19.9) (275)	119.9 (37.0) (N = 3073)	125.0 (17.2) (N = 1915)	123.4 (25.1) (N = 2915)	151.9 (16.2) (N = 1302)
2005	190.9 (24.3) (N = 414)	196.5 (22.5) (N = 412)	134.4 (26.8) (N = 641)	137.4 (18.4) (N = 876)	153.4 (14.3) (N = 2692)	164.6 (16.8) (N = 716)
2006	194.0 (23.7) (N = 2327)	191.3 (26.8) (N = 203)	131.0 (36.7) (N = 2586)	145.1 (26.4) (1032)	141.0 (26.4) (N = 1968)	158.3 (20.2) (N = 473)

Table 4. Major Hatcheries Producing Chinook salmon (90%) in the Strait of Georgia and the recovery of CWT's two times over expected, 1997-2005

Hatchery	**% of recaptures that exceeded 2x expected (N=706)**
Puntledge	53 %
Nanaimo	40 %
Spius	27 %
Little Qualicum	27 %
Big Qualicum	20 %
Powell River	13 %
Shuswap	13 %
Quinsam	0 %
Cowichan	0 %
Chilliwack	0 %
Chehalis	0 %
Tenderfoot	0 %

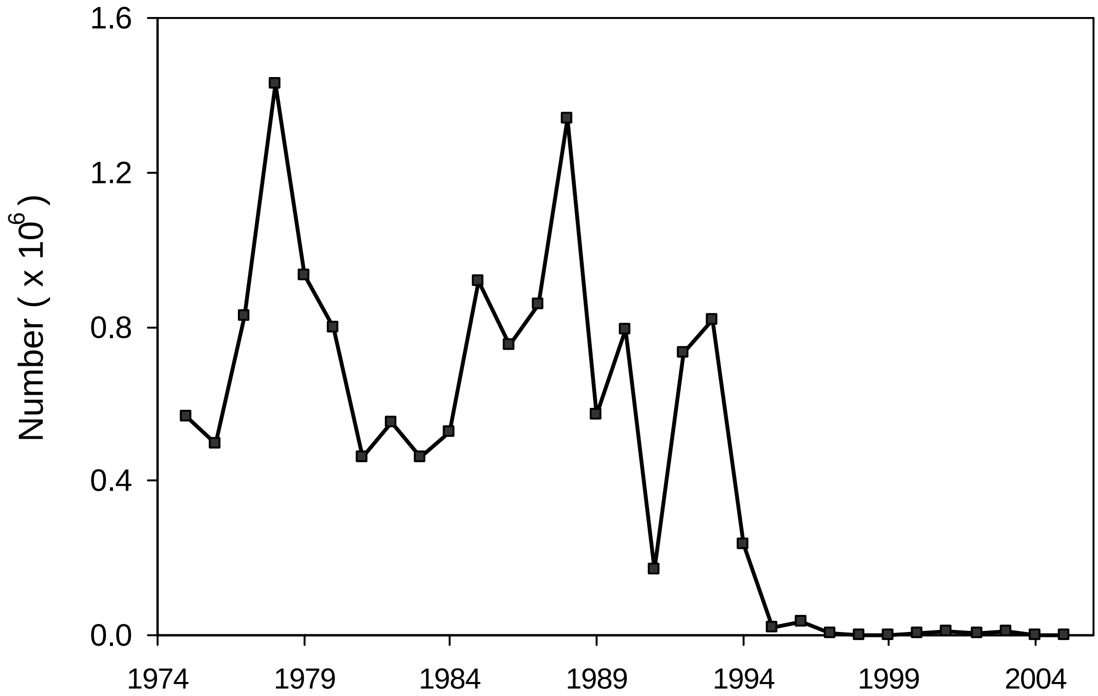

Figure 1. Catch of coho salmon in the commercial and sports fisheries in the Strait of Georgia from 1975 to 2005.

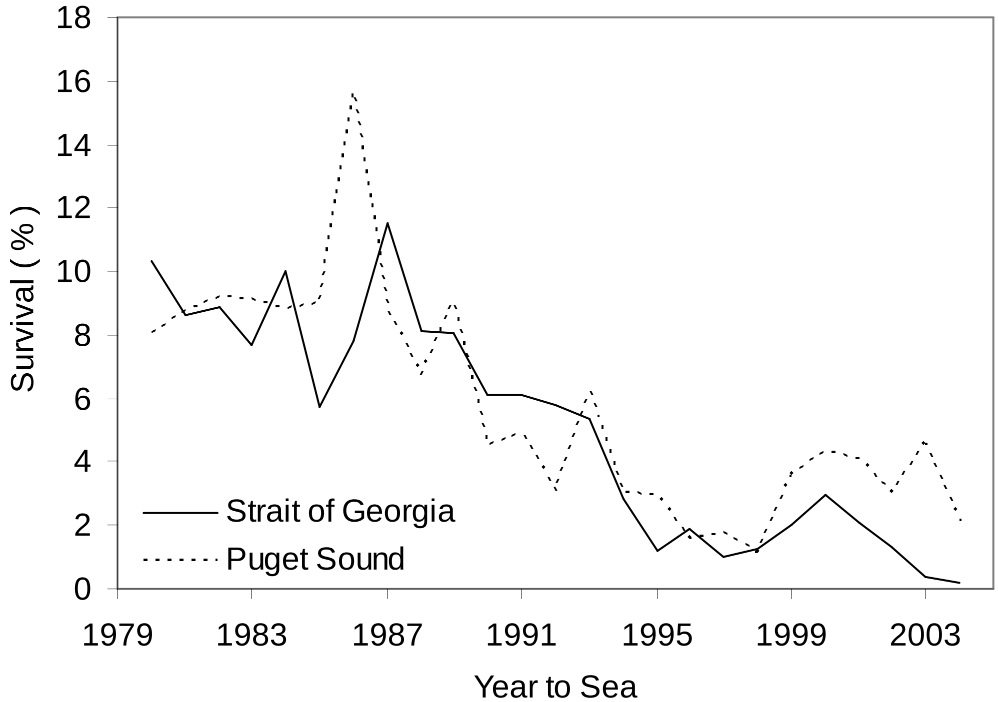

Figure 2. The marine survival of coho salmon released from hatcheries in the Strait of Georgia and Puget Sound 1980 to 2004.

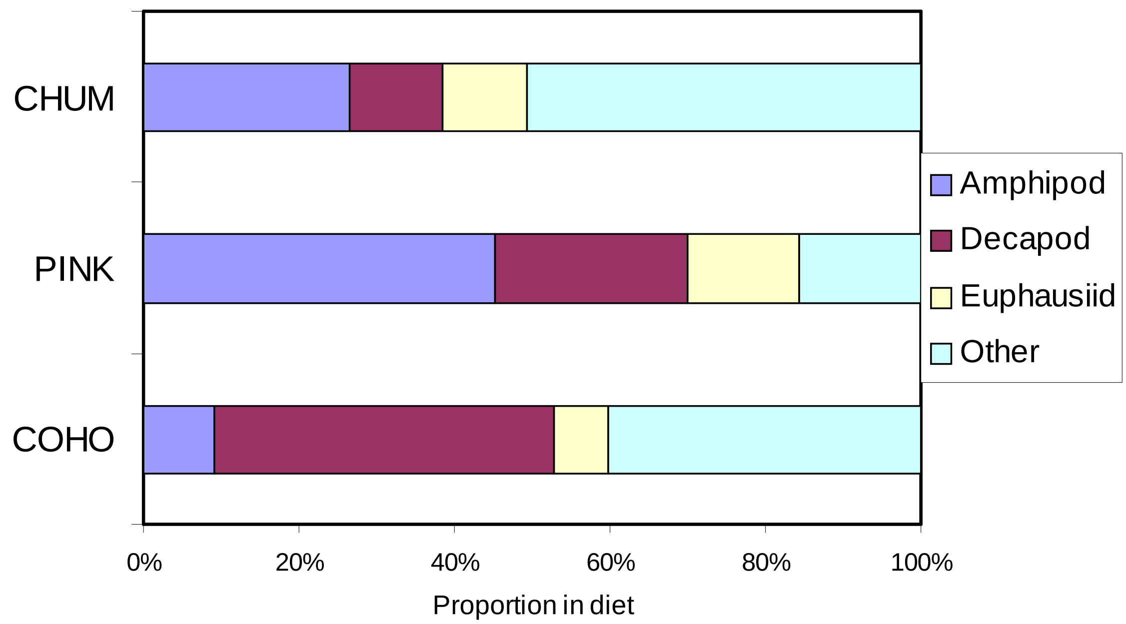

Figure 3. Major diet items of juvenile pink, chum and coho salmon caught in the Strait of Georgia 1997-2004.

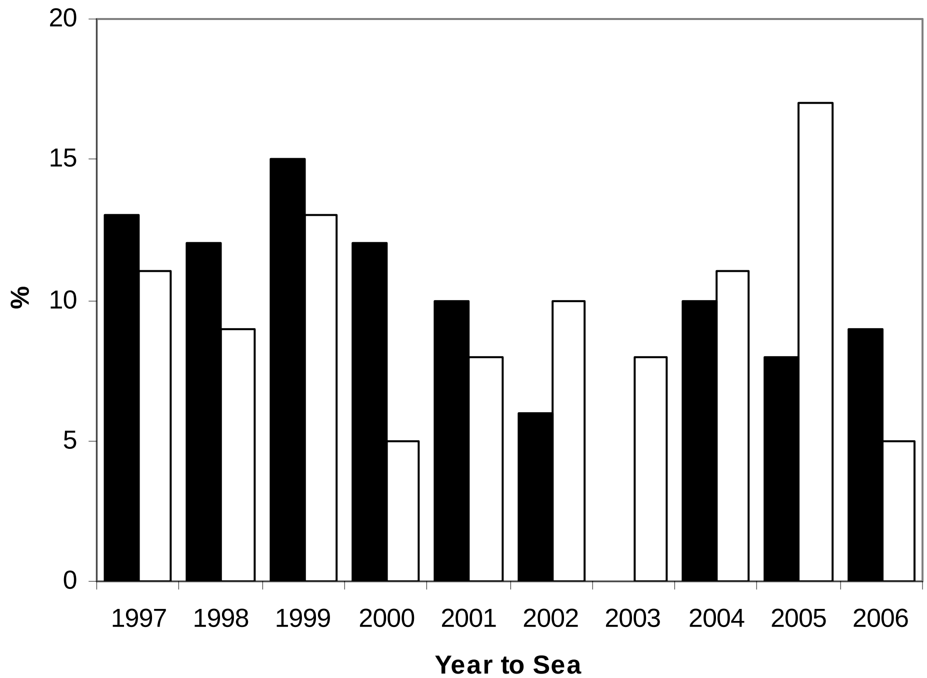

Figure 4. The percent of hatchery coho sampled in the Strait of Georgia in July ■ and September □ that originated from Puget Sound hatcheries. There was no survey in July 2003.

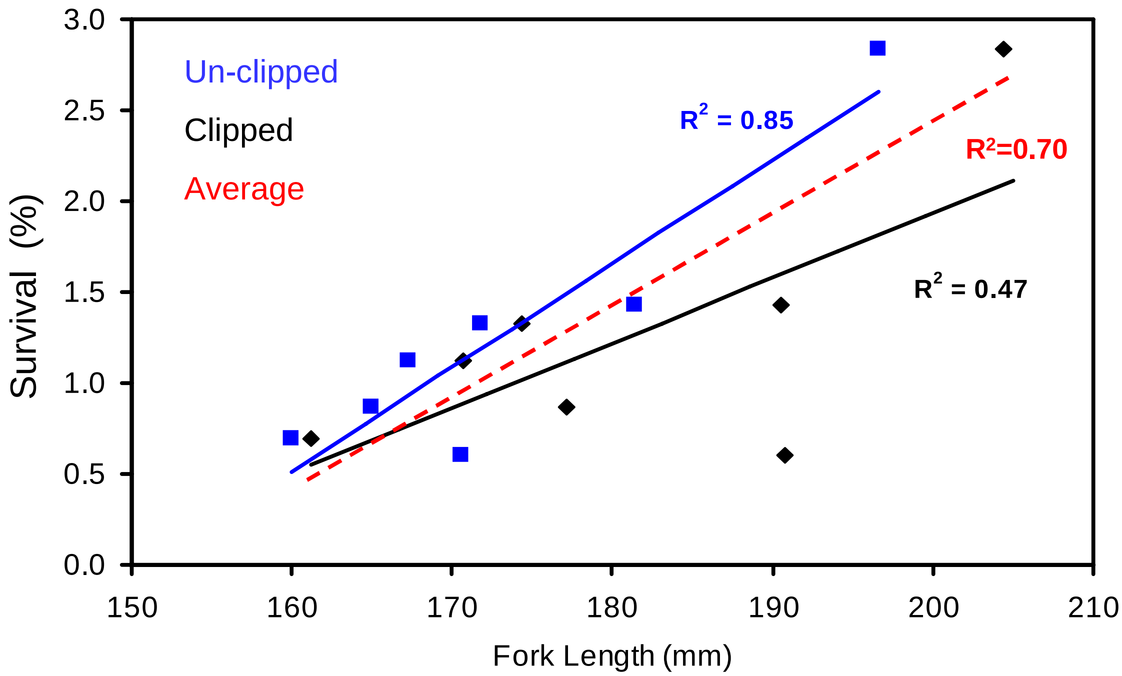

Figure 5. Marine survival of coho salmon, with adipose clipped fins (hatchery) and without the adipose fin removed (wild) in the Strait of Georgia.

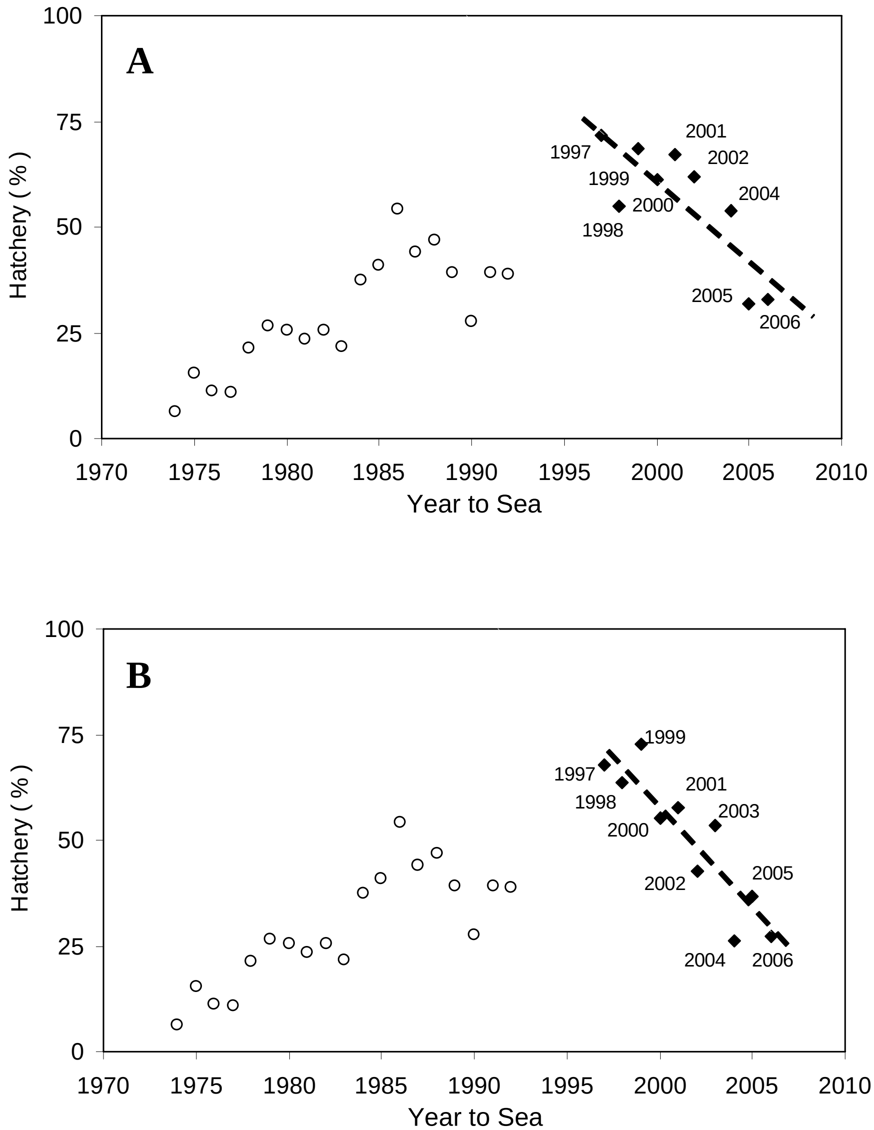

Figure 6. Percentage of Strait of Georgia coho salmon from Canadian hatcheries. A) July 1974 – 2006. B) September 1974-2006. Open circles are from Sweeting et al. (2003). The solid diamonds are from this study. The r^2 relates to the dashed line for the estimates from 1997-2006. (There was no survey in July 2003).

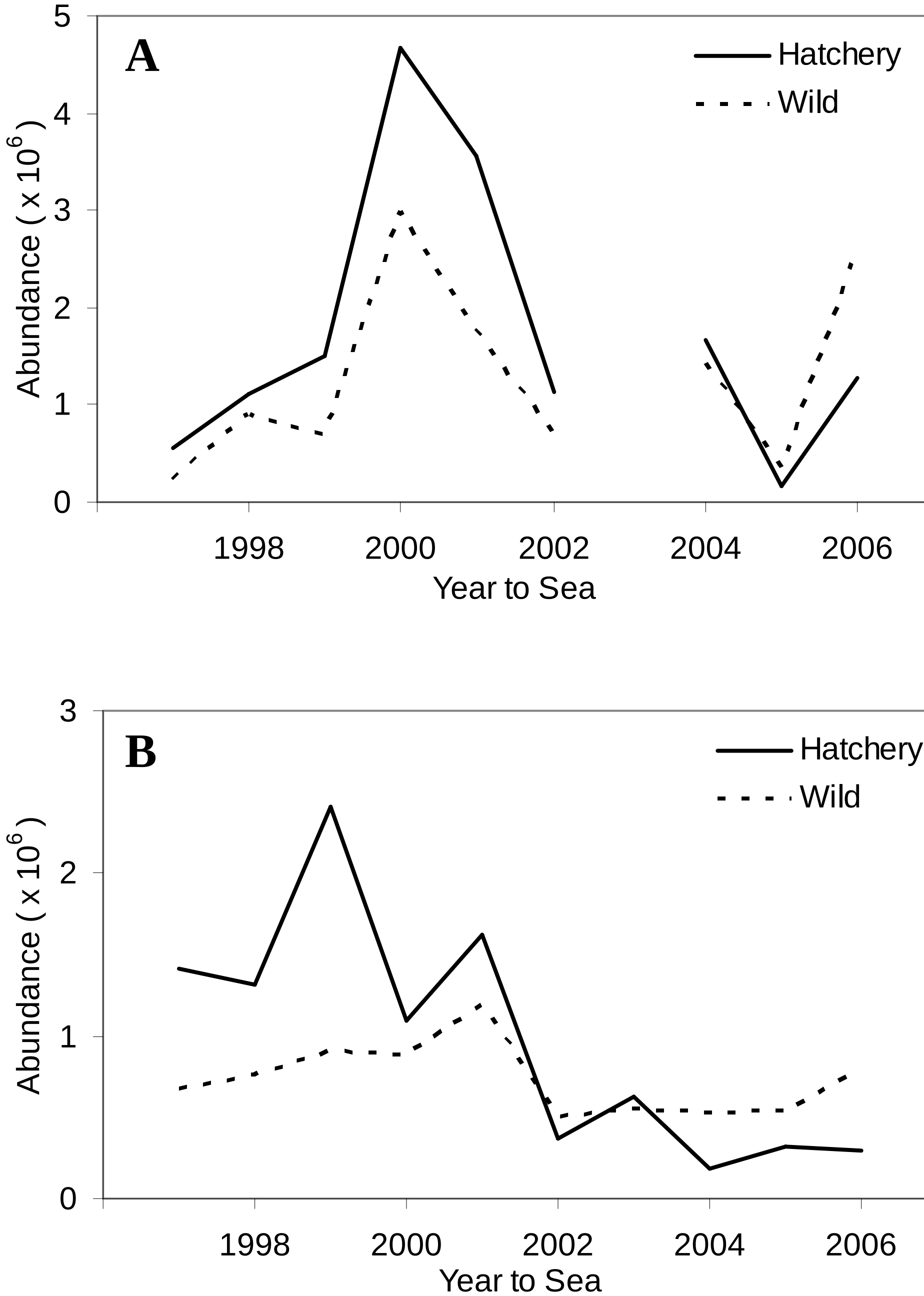

Figure 7. Abundance estimates for hatchery and wild coho salmon in the Strait of Georgia from 1997 to 2006. A) July surveys. B) September surveys. There was no survey in July 2003.

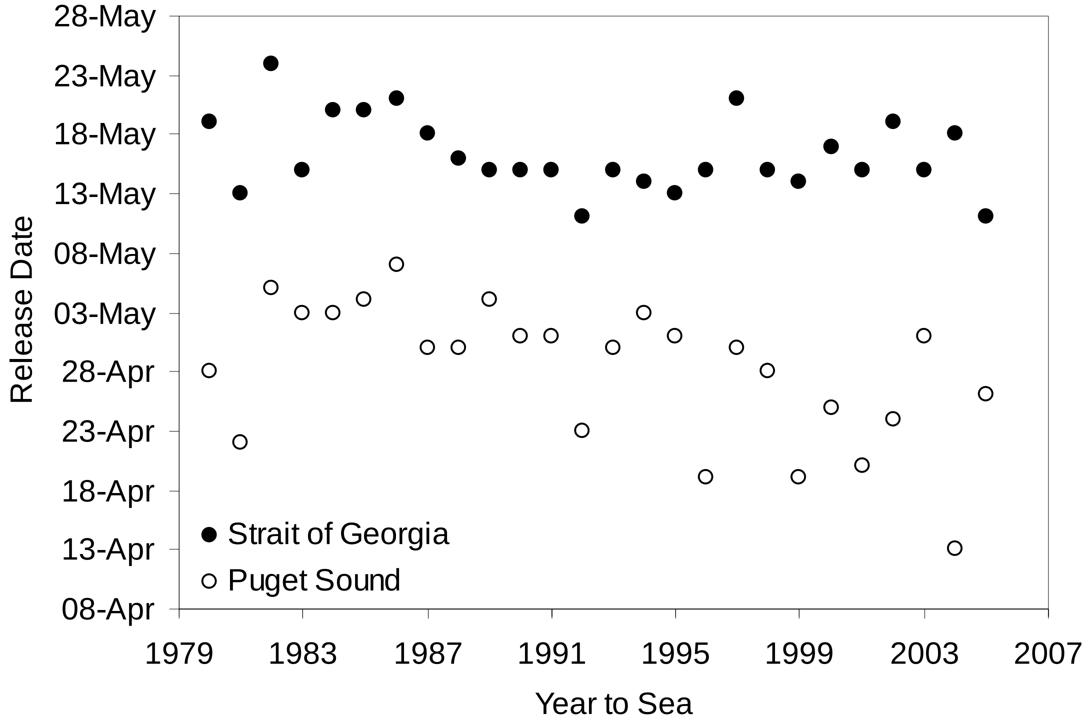

Figure 8. The date at which approximately 50% of coho salmon smolts were released from all hatcheries into the Strait of Georgia and Puget Sound, 1980-2005.

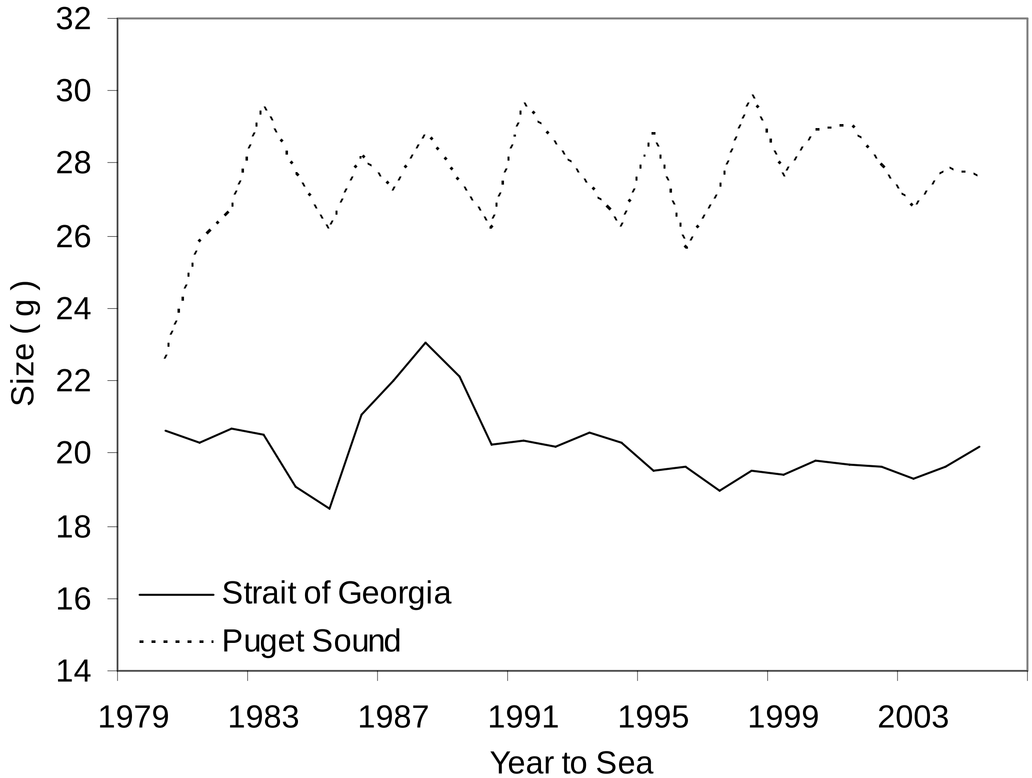

Figure 9. The average weight of coho salmon released from hatcheries around the Strait of Georgia and Puget Sound, 1980-2005.

<u>Budget summary:</u> Mechanisms regulating the production of coho, chinook and steelhead in the Strait of Georgia and Puget Sound.

The project encountered no major budget issues and managed to stay on budget with the exception of a few line items. These items are itemized below. Items that exceeded projected costs were covered by DFO and no additional funding was requested from the PSC. Spreadsheet of expenditures attached separately (*Beamish PSC final report_budget.xls*).

1. **Salary.** Salary expenditures for term technicians and field staff exceeded projected costs. This was due to the extension of the project through the 2006 field season. On the attached budget is indicates an overrun of approximately 5K. The actual additional costs of term technical assistance would have been over 12K, however, these costs were covered by other DFO programs.
2. **Meeting and Field work:** There were 1.7K additional expenses for this line item due to the additional field work in 2006.
3. **Field Supplies:** There were 2.6K additional expenses for field supplies due to the additional field work in 2006.
4. **DNA:** The number of samples processed for DNA was smaller than anticipated and therefore expenditures were 0.6K less than projected.
5. **Synthesis meetings:** In the proposal, we had proposed 3 synthesis meetings of researchers participating in this project. Due to the schedules of the various participants and restrictions on travel in various Departments, this did not occur as planned. Instead, multiple conference calls occurred between researchers over the span of the project. In addition, side meetings were made at conferences where multiple researchers involved in the project were in attendance. Therefore, the projected cost for this line item was much lower than projected.
6. **Publication costs:** The anticipated costs for publication have been lower than projected primarily because the costs have not yet been incurred. Although papers have been submitted to NPAFC over the past two years, the results are just being submitted to the primary literature. The publication costs incurred to date include typing, figure preparation and editing costs.

<u>Appendix A.</u> Copy of "Changes in the trend in the percentages of hatchery and wild coho salmon in the Strait of Georgia." R.J. Beamish, R.M. Sweeting, K.L. Lange and C.M. Neville. Submitted to Transactions American Fisheries Society.

" please attach PDF file "Changes in SOG coho" here"

<u>Appendix B. Additional reports.</u>

Beamish, R.J., Sweeting, R.M., Neville, C.M. and Lange, K. 2006. Hatchery and wild percentages of coho salmon in the Strait of Georgia are related to shifts in species dominance. NPAFC Doc. 981. Fisheries & Oceans Canada, Science Branch – Pacific Region, Pacific Biological Station, Nanaimo, BC V9T 6N7, Canada. 21 p. (copy attached)

<u>Abstracts</u>

Beamish, R., R. Sweeting, C. Neville and K. Lange. Shifts in trends in the dominance of Pacific salmon in the Strait of Georgia are related to life history strategies, regimes and climate warming. (PICES, 2006).

The Strait of Georgia is a semi-enclosed marine ecosystem on Canada's Pacific coast that is the major rearing area for juvenile Pacific salmon (Oncorhynchus spp.). Profound changes in the rearing capacity for the various species of salmon have occurred over the past 40 years that are related to regimes and the life history strategies of each species. Chinook and coho salmon benefited from the ecosystem organization prior to the 1977 regime shift. Sockeye salmon productivity peaked in the 1977-1989 regime, but was poor in the regime from 1990-1998. Chum and pink salmon production is at historic high levels following the 1998 regime shift.

In 2005, survey catches of juvenile coho and chinook salmon were the lowest in a nine year study, while catches of juvenile chum salmon were the record highest. We propose that these shifts in species specific marine survival trends occur because of shifts in the timing and/or intensity of the spring bloom in relation to marine entry times. The mechanism relates to the amount of growth in the early marine period and to the specific life history strategies. A general warming trend and the use of hatcheries affects the ability of a species to adapt to changes in the organization of the ecosystem. Recognition of environmentally-related trends in survival at the early marine stage should be a consideration in the development of strategic management plans for Pacific salmon that pass through the Strait of Georgia.

Sweeting, R., R. Beamish and C. Neville. Comparison of juvenile salmon diets in the Strait of Georgia and Puget sound 1997-2006. (2007 Georgia Basin Puget sound Research Conference).

Juvenile Pacific salmon (Oncorhynchus spp) enter the ocean in the early spring/summer. In the Strait of Georgia and Puget Sound they generally spend several weeks to months rearing before migrating to other areas. During this time, growth and predation avoidance are the major priorities, and interspecific competition for food could be a limiting factor in successful migration and/or overwinter survival. This report will present the results of 10 years of summer (July) and fall (September) surveys in Puget Sound and the Strait of Georgia, during which stomach data was collected for several thousand juvenile coho (*O. kisutch*), Chinook (*O. tshawytscha*), and chum (*O. keta*) salmon. In addition to examining similarities and differences in dietary preferences, the influence of size, season, and environment will be discussed.

Beamish, R., and R. Sweeting. Distribution information from coded-wire tag recoveries of juvenile coho and chinook salmon released into the Strait of Georgia and Puget Sound from 1997 to 2007.

We report the results of an analysis of over 5000 coded-wire tag recoveries of ocean age 0 coho and Chinook salmon captured in our surveys from 1997 to 2007. In the July surveys, a consistent percentage of about 10-15% of the tagged coho in the Strait of Georgia were from Puget Sound. Most (92%) of these coho were from the Nooksack and Skagit River areas (WA01 and WA02). No tagged coho released into the Strait of Georgia were found in Puget Sound and few coho from WA01 and WA02 were captured south of their release areas. Recoveries in Juan de Fuca Strait and off the west coast of Vancouver Island were virtually all from releases from Puget Sound from areas WA01 and WA02. In the September surveys, the number of tagged coho in the Strait of Georgia remained high, while recaptures in Puget Sound dropped dramatically. There were large increases in tag recaptures in Juan de Fuca Strait and off the west coast of Vancouver Island, with most of these coho originating from the southern part of Puget Sound (WA03 to WA05).

About 10% of the tagged juvenile Chinook salmon recaptured in the Strait of Georgia in July were from Puget Sound and virtually all were from WA02 and WA02. Only one chinook released into the Strait of Georgia was recaptured in Puget Sound. In September, the percentage of tagged coho released in Puget Sound and recaptured in the Strait of Georgia remained unchanged except that most of these coho came from WA)#, WA04 and WA05. Unlike coho, large numbers of tagged Chinook salmon were captured in Puget Sound in September. About 3% of these recaptures were originally released off Canada. Catches in Juan de Fuca and off the west coast of Vancouver Island indicated that chinook salmon from Puget Sound and the Strait of Georgia were moving offshore.

In general, the pattern of releases and recaptures indicated that coho released into the Strait of Georgia virtually never enter Puget Sound and only a few percent of the Chinook released in the Strait of Georgia enter the sound. Virtually all the coho released in Puget Sound and captured in the Strait of Georgia were from the Skagit/Nooksack area. In fact these coho were not common in our catches in Puget Sound south of this area. Tag recaptures showed that most coho left Puget Sound In August and the Strait of Georgia after September. Chinook remained in Puget Sound through September.

Beamish, R.J., R.M. Sweeting, C.M. Neville, and Krista L. Lange. 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. Extended abstract for NPAFC Technical Report 7: 49-51.

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 15m 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).

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 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, pers. comm., http://www.eos.ubc.ca/~sallen/kcollins.pdf). 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 DFO (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 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 (Fig. 7). 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