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1997 Forecasts of Marine Survival and Catch Distribution for Strait of Georgia Coho Salmon

by

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1. Introduction

Forecasts of the marine survival rate and ocean distribution of Strait of Georgia coho and the abundance of coho in the WCVI troll fishery are required for managing the 1997 southern British Columbia coho salmon fishery. Forecasts were first provided through PSARC for the 1996 season (PSARC Working Paper S96-11. This paper presents 1997 forecasts using similar methodologies used in 1996.

2. Forecast of Marine Survival Rate

Marine survival rates for Strait of Georgia hatchery and wild coho stocks are presented in Table 1.

Strait of Georgia coho are almost entirely three years of age at maturity. Returns of adult coho in 1997 are therefore the progeny of coho that spawned in 1994, were fry in 1995, and seaward migrating smolts in 1996. There are longer time series of the data required to develop forecasting methodologies for certain Strait of Georgia hatchery stocks than for wild stocks in the same area. Marine survival rates of wild stocks have trended in a similar way to hatchery stocks so inferences about wild stock marine survival rates can reasonably be made from forecasts for hatchery stocks
(Figure 1.).

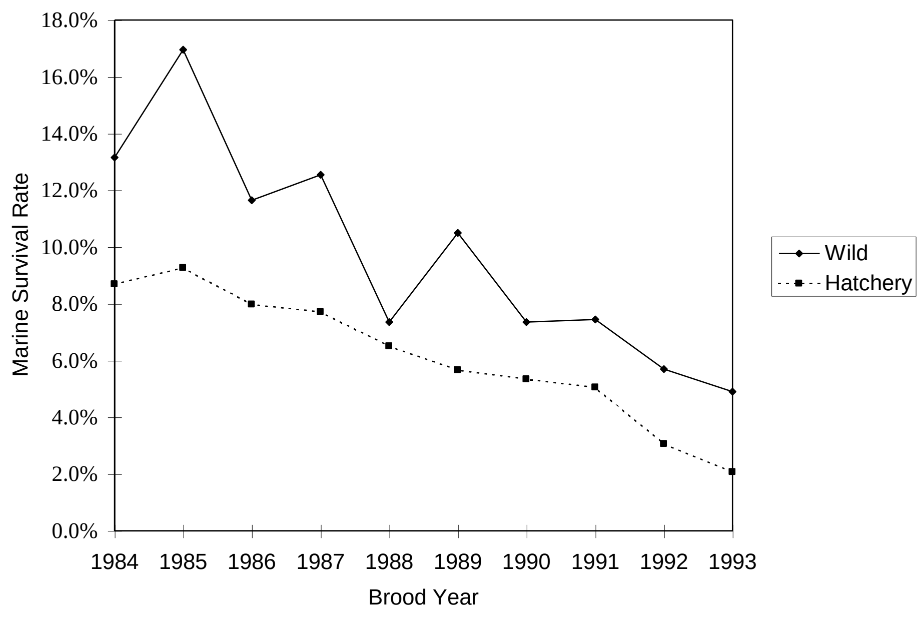

Figure 1. Average marine survival rate for 2 wild coho stocks (Black Creek and Salmon River) and 3 hatchery coho stocks (BQR, Quinsam, Inch).

Table 1. Percent smolt to adult survival rate for six hatchery and three wild coho indicator stocks.

Brood Year	Hatchery Indicator Stocks						Wild Indicator Stocks		
	Quinsam	Puntledge[1]	BQR	Inch	Chehalis[2]	Chilliwack[5]	Black	Salmon	Mesachie
1973			28.7						
1974	5.8		15.1						
1975	9.5		14.6						
1976	6.4	32.5	19.2				21.4		
1977	8.8	12.6	27.0				23.9		
1978	6.3	11.4	11.7						
1979	4.6	8.0	10.3						
1980	5.7	8.2	11.2			12.0			
1981	5.1	6.4	7.9			14.3			
1982	7.9	14.3	5.0	6.8		18.3			
1983	6.8	9.6	1.0	6.1	11.9	10.0	12.5		
1984	8.4	4.2	0.7	8.6	13.4	16.9	11.4	15.4	
1985	8.0	4.1	1.7	20.6	12.3	18.2	12.7	21.9	6.9
1986	10.2	3.3	1.3	11.1	12.5	12.4	11.3	13.5	4.9
1987	7.7	2.4	4.7	8.1	10.5	10.7	12.4	13.4	7.0
1988	4.2	3.9	6.3	6.8	7.9	9.1	7.6	7.8	3.2
1989	5.8	2.1	5.5	9.8	10.0	5.7	12.1	9.6	2.5
1990	3.5	3.2	6.7	8.3	8.5	5.9	6.3	8.4	2.0
1991	2.3	0.6	6.5	6.0	5.5	6.4	5.4	9.5	2.7
1992	2.5	2.0	3.0	5.5	3.6	3.7	4.5	6.9	
1993[3]	0.9	1.8	1.5	(5.0[4])	(5.8[4])	3.8	2.4	7.4	

1 Survival to fishery divided by BQR Hatchery exploitation rate to give estimated total survival rate.
2 Survival to fishery divided by Inch Hatchery exploitation rate to give estimated total survival rate.
3 1993 brood year survival rates are preliminary because US catches are not available yet.
4 Probable over-estimate. Total survival was calculated by dividing survival to the fishery by the Chilliwack Hatchery
5 Chilliwack survivals are probably under-estimated due to significant unknown catches in-river.

2.1 Quinsam River Hatchery

Marine survival rate data are available for the Quinsam River hatchery stock from 1974 (brood year) to the present. The survival of Black Creek coho, a nearby wild stock, has been consistently higher than the survival of Quinsam River coho but has trended in a similar manner (Fig. 2).

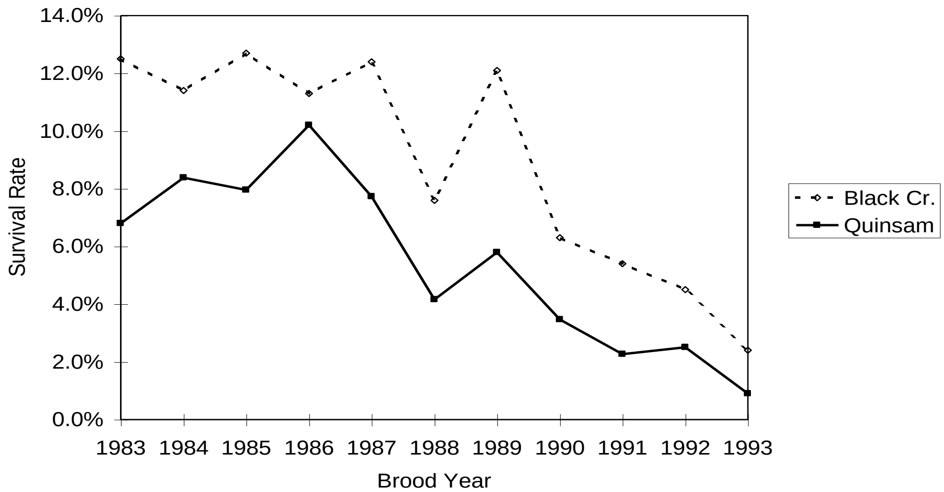

Figure 2. Marine survival rates of Black Creek wild and Quinsam River hatchery coho, 1983 - 1993 brood years.

Three approaches to forecasting the marine survival rate of Quinsam River hatchery coho were evaluated in the previous PSARC working paper. The 3-year cycle average was selected as the best approach given the declining survival rates observed since the late 1980's. A sibling regression model which uses jack returns to predict the return of age 3 coho in the following year over-estimated the survival rate in recent years.

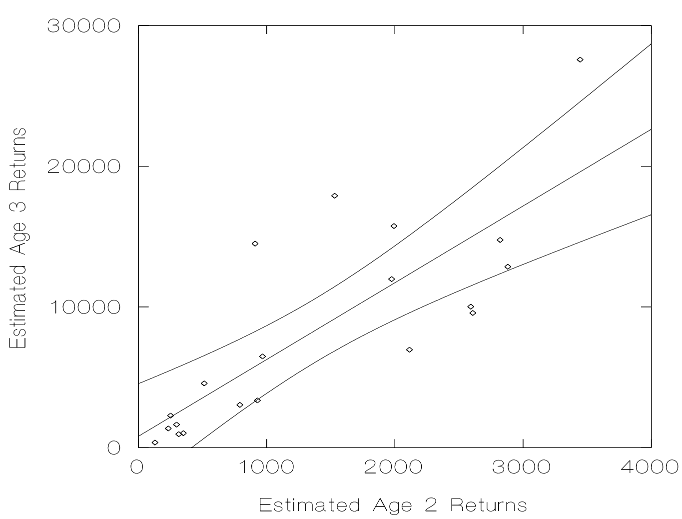

Figure 3. Estimated return of age 3 coho versus the estimated return of age 2 coho from the same brood year for Quinsam River hatchery coho. Brood years are 1974 to 1993. Estimated returns are based on CWT recoveries expanded for fishery and escapement sampling rates. A linear regression line and the 90 percent confidence limits about the regression are also indicated.

Table 2. Retrospective analysis and forecasts for Quinsam River hatchery coho using a sibling regression model. A 3 year running average is provided for comparison.

	Regression parameters and statistics							
	a	b	r^2	p				
1990	3753	4.253	0.305	<0.05				
1991	2743	4.640	0.374	<0.05				
1992	2109	4.906	0.453	<0.01				
1993	1885	5.001	0.504	<0.001				
1994	1583	5.130	0.548	<0.001				
1995	1248	5.269	0.581	<0.001				
1996	979	5.380	0.607	<0.001				
1997	811	5.454	0.632	<0.001				
	Age 2	Age 3	Age 3				Forecast	Previous
	Actual	Forecast	Actual	Abs Dev	Abs % err	Smolt Rel	Survival	3-yr Ave.
1990	791.00	7117	3041	4076	57.3%	39632	0.180	0.088
1991	297.00	4121	1641	2480	60.2%	39466	0.104	0.086
1992	251.00	3340	2283	1057	31.7%	39400	0.085	0.073
1993	233.00	3050	1368	1682	55.2%	39411	0.077	0.059
1994	315.00	3199	963	2236	69.9%	42470	0.075	0.045
1995	350.00	3092	1030	2062	66.7%	43742	0.071	0.038
1996	129.00	1673	365	1308	78.2%	38947	0.043	0.027
1997	128.00	1509				80125	0.019	0.019
			Mean	2129	59.9%			

The marine survival rate of Quinsam River hatchery coho is estimated at 0.019 based using a sibling regression model. The previous 3-year average survival rate is also 0.019. From these estimates we can conclude that marine survival of the 1994 brood returning in 1997 will not likely improve over that experienced by the 1993 brood and may be slightly lower. Caution should be exercised in 1997 since both the sibling regression model and the 3 year average have over-estimated the actual marine survival rate during the recent decline in marine survival rate. For wild stocks, marine survival rate is expected to be slightly higher than for hatchery stocks based on the relationship between the two described above.

3. Forecasting Catch Distribution

The distribution of the catch of Strait of Georgia coho has high inter-annual variability, but is synchronous among stocks within a year (Fig. 4). The ability to forecast the distribution of catch, especially in extreme years is of great importance to managers in establishing fishing plans; you have to know where the fish will be if you want to manage their harvest. Out-migration of coho from the Strait of Georgia through Juan de Fuca Strait can occur from the first ocean summer until the following spring. The mechanism controlling the proportion of a stock which stays in the Strait of Georgia and the proportion which migrates to the west coast of Vancouver Island and the central coast is unknown. Because the mechanism is unknown, but acts on all coho stocks simultaneously, an environmental variable that might be correlated with relevant biological processes was investigated and reported on in PSARC Working Paper S96-8. Salinity was found to be related to smolt survival at the time of their entry to the ocean.

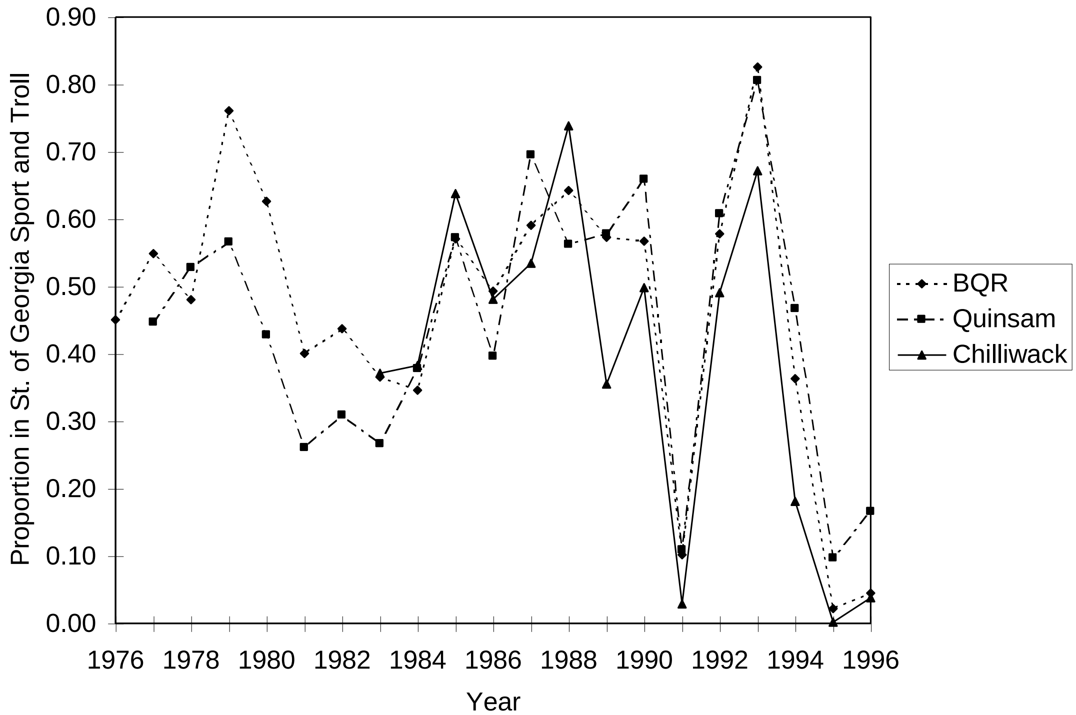

Figure 4. The proportion of the catch of three Strait of Georgia hatchery coho stocks caught in Strait of Georgia sport and troll fisheries.

The mean February salinity at the Chrome Island and Sisters Island lighthouses was used to generate the forecasts in Table 2. In WP S96-8, the February Chrome Island salinity was used, however, last year at this time there was concern for the continuation of salinity readings from Sisters Island once the lighthouse was closed. It was noted in WP S96-8 that the mean Chrome/Sisters salinity had a higher correlation with catch distribution than did each of the lighthouses separately. Note that the precision of forecasts is low and they should therefore primarily be used to indicate the expected character of distribution.

Table 3. Retrospective analysis and 1997 forecasts of the proportion of the catch of three Strait of Georgia hatchery coho stocks in Strait of Georgia sport and troll fisheries. Salinity is the mean February salinity for Chrome Island and Sisters Island lighthouses.

		Regression parameters and statistics									
Quinsam		n	a	b	r^2	p	Salinity	Forecast	Actual	Abs Dev	Abs % err
	1990	13	-4.232	0.163	0.487	<0.01	29.05	0.503	0.659	0.156	31.0%
	1991	14	-4.46	0.171	0.468	<0.01	27.00	0.157	0.109	0.048	30.6%
	1992	15	-4.821	0.184	0.639	<0.001	27.40	0.221	0.608	0.387	175.6%
	1993	16	-3.289	0.131	0.341	<0.01	29.35	0.556	0.806	0.250	45.0%
	1994	17	-3.789	0.149	0.373	<0.01	28.75	0.495	0.467	0.028	5.6%
	1995	18	-3.784	0.149	0.374	<0.01	27.70	0.343	0.097	0.246	71.7%
	1996	19	-4.393	0.170	0.428	<0.01	26.90	0.180	0.166	0.014	7.8%
	1997	20	-4.404	0.170	0.493	<0.001	27.15	0.212			
									Mean	0.161	52.5%
		Regression parameters and statistics									
BQR		n	a	b	r^2	p	Salinity	Forecast	Actual	Abs Dev	Abs % err
	1990	14	-4.227	0.165	0.644	<0.001	29.05	0.566	0.567	0.001	0.1%
	1991	15	-4.233	0.165	0.650	<0.001	27.00	0.222	0.102	0.120	54.1%
	1992	16	-5.037	0.193	0.793	<0.001	27.40	0.251	0.578	0.327	130.1%
	1993	17	-3.749	0.149	0.541	<0.001	29.35	0.624	0.826	0.202	32.3%
	1994	18	-4.18	0.164	0.545	<0.001	28.75	0.535	0.363	0.172	32.1%
	1995	19	-4.146	0.162	0.507	<0.001	27.70	0.341	0.022	0.319	93.6%
	1996	20	-4.995	0.192	0.523	<0.001	26.90	0.170	0.045	0.125	73.5%
	1997	21	-5.398	0.205	0.612	<0.001	27.15	0.168			
									Mean	0.181	59.4%
		Regression parameters and statistics									
Chilliwack		n	a	b	r^2	p	Salinity	Forecast	Actual	Abs Dev	Abs % err
	1990	7	-5.571	0.21	0.623	<0.05	29.05	0.530	0.498	0.032	5.9%
	1991	8	-5.507	0.208	0.624	<0.05	27.00	0.109	0.029	0.080	73.4%
	1992	9	-6.192	0.231	0.848	<0.001	27.40	0.137	0.491	0.354	257.4%
	1993	10	-4.467	0.172	0.567	<0.01	29.35	0.581	0.672	0.091	15.6%
	1994	11	-4.697	0.18	0.605	<0.01	28.75	0.478	0.181	0.297	62.1%
	1995	12	-4.602	0.176	0.46	<0.01	27.70	0.273	0.002	0.271	99.3%
	1996	13	-5.474	0.206	0.509	<0.01	26.90	0.067	0.038	0.029	43.6%
	1997	14	-5.6	0.21	0.595	<0.01	27.15	0.102			
									Mean	0.165	79.6%

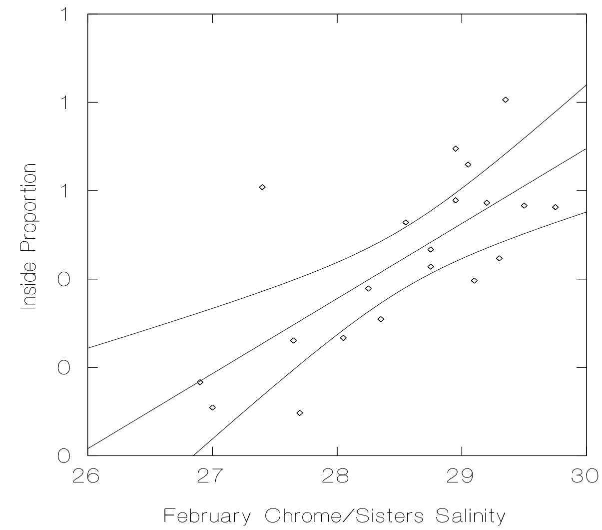

Figure 5. Proportion of Quinsam River hatchery coho catch in the Strait of Georgia sport and troll fisheries, 1977-1996, versus the average sea-surface salinity in February at Chrome and Sisters Island lighthouses (regression line and 90% confidence limits).

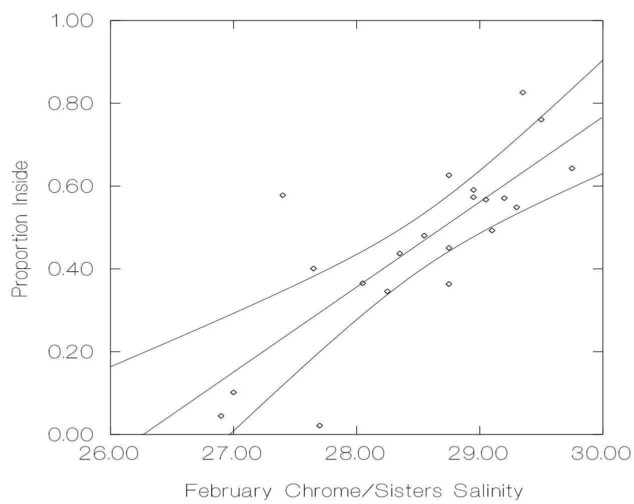

Figure 6. Proportion of Big Qualicum River hatchery coho catch in the Strait of Georgia sport and troll fisheries, 1977-1996, versus the average sea-surface salinity in February at Chrome and Sisters Island lighthouses (regression line and 90% confidence limits).

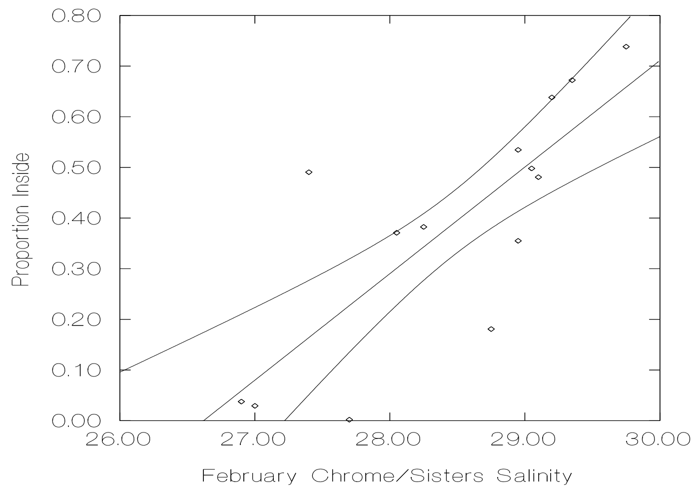

Figure 7. Proportion of Chilliwack River hatchery coho catch in the Strait of Georgia sport and troll fisheries, 1983 -1996, versus the average sea-surface salinity in February at Chrome and Sisters Island lighthouses (regression line and 90% confidence limits).

The forecast distribution in Strait of Georgia fisheries of all three hatchery stocks is expected be similar to the forecast for 1996. A very low proportion of the catch of Strait of Georgia coho is predicted to occur in Strait of Georgia fisheries and a high proportion is expected to occur off the west coast of Vancouver Island (assuming historical fishing patterns).

Information from research trawl surveys in the Strait of Georgia and Juan de Fuca Strait in February also confirms a distribution of coho to outside fishing areas in 1997 (R. Beamish, pers. com.). No coho were caught in tows inside the strait while several hundred were caught in the Strait of Juan de Fuca. Anecdotal information from recreational fishermen also indicates a very low abundance of coho inside the Strait of Georgia through the month of April (T. Gjernes, pers. com.). Low catches in the early part of the year are indicative of low catches later in the year.

4. Forecast of WCVI Troll Fishery Abundance

Coho abundance in the WCVI troll fishery was forecasted prior to the 1996 fishing season as the basis for the catch ceiling developed for that fishery (PSARC WP S96-11). The methodology used in that analysis is described below with some minor modifications. The approach involves a reconstruction of the coho abundance in the WCVI troll fishing area and a means of predicting it using the marine survival rates and catch distribution forecasts presented in earlier sections of this paper.

Historical abundance is calculated by dividing the total season coho catch in the fishery by the WCVI troll fishery harvest rate on Robertson Creek hatchery coho (see Equations 1 and2 below). This is a reconstruction of the abundance of all coho stocks contributing to this fishery and includes, Canadian and U.S. hatchery and wild stocks

The WCVI troll harvest rate is calculated as follows:

$$HR_{TR} = \frac{C_{TR}}{(E + C_{TR} + C_{SP} + C_{N})}$$

Eqn. 1

where:

HR_{TR}: the WCVI troll fishery harvest rate on Robertson Creek coho

C_{TR}: the expanded CWT catch of Robertson Creek coho in the WCVI troll fishery

C_{SP}: the expanded CWT catch of Robertson Creek coho in the WCVI marine and freshwater sport fisheries

C_{N}: the expanded CWT catch of Robertson Creek coho in WCVI net fisheries

E: the expanded CWT escapement of Robertson Creek coho

Estimated abundance in the WCVI troll fishing area is then estimated as,

$$AB_{TR} = \frac{C_{WCTR}}{HR_{TR}}$$

Eqn. 2

where:

AB_{TR}: the abundance in the WCVI troll fishing area

C_{WCTR}: the total coho catch in the WCVI troll fishery

Abundance in the WCVI troll fishing area calculated in this manner for the years 1976 through 1996 is presented in Table 3.

Table 3. Abundance in the WCVI troll fishing area calculated as per equation 2.

Year	Catch	Harvest Rate	Abundance
1976	1,640,259	0.639	2,568,167
1977	1,567,879	0.523	2,997,436
1978	1,360,274	0.472	2,882,575
1979	1,912,878	0.593	3,225,469
1980	1,738,470	0.472	3,685,606
1981	1,385,323	0.572	2,420,830
1982	1,777,436	0.722	2,462,049
1983	2,167,438	0.619	3,504,280
1984	2,172,166	0.691	3,145,105
1985	1,389,055	0.599	2,318,911
1986	2,156,833	0.555	3,884,005
1987	1,821,022	0.477	3,814,451
1988	1,595,801	0.521	3,060,861
1989	1,952,009	0.569	3,430,776
1990	1,863,608	0.573	3,251,885
1991	1,889,946	0.488	3,869,267
1992	1,671,822	0.603	2,773,189
1993	953,811	0.649	1,470,509
1994	1,251,817	0.623	2,010,461
1995	1,345,333	0.405	3,324,883
1996	782,657	0.333	2,353,016

To produce a pre-season forecast of the reconstructed WCVI abundance a multiple regression model was formulated (Equation 3) using the following parameters as independent variables; Quinsam River marine survival rate (A3Q)and the proportion of Quinsam River coho caught in St. of Georgia sport and troll fisheries (INQ). Note that the regression was calculated using data from 1986 to 1996 only. This is because the wide range in abundance in the 1990's can best be explained by the downward trend in marine survival of St. of Georgia coho since the mid-1980's and the extreme fluctuations in the catch distribution of St. of Georgia coho in the 1990's. The survival of WCVI coho as indicated by Robertson Creek hatchery coho is a useful variable in explaining the variability in abundance if the entire time series (back to 1976) is used.

$$\text{abundance} = 2{,}814{,}486 - 2{,}784{,}399 * \text{INQ} + 27{,}539{,}100 * \text{A3Q}$$

$$n = 11;\ \text{adj. } r^2 = 0.774;\ p = 0.001 \qquad \text{Eqn. 3}$$

A comparison of predicted abundance using this regression formula and the abundance reconstructed above is presented in Figure 8. We would expect abundance in the WCVI troll fishing area to vary directly with the survival rate of contributing stocks and inversely with the proportion of Strait of Georgia coho caught in inside fisheries (the WCVI troll fishery is the major outside fishery harvesting Strait of Georgia coho). Of course the utility of Equation 3 as a forecasting tool is limited by the fact that both the distribution and survival rate of Quinsam River coho are themselves forecasts with associated uncertainty. Based on this regression, the forecast of abundance in the WCVI troll fishing area in 1997 is 2,753,000 (90% conf. limits).

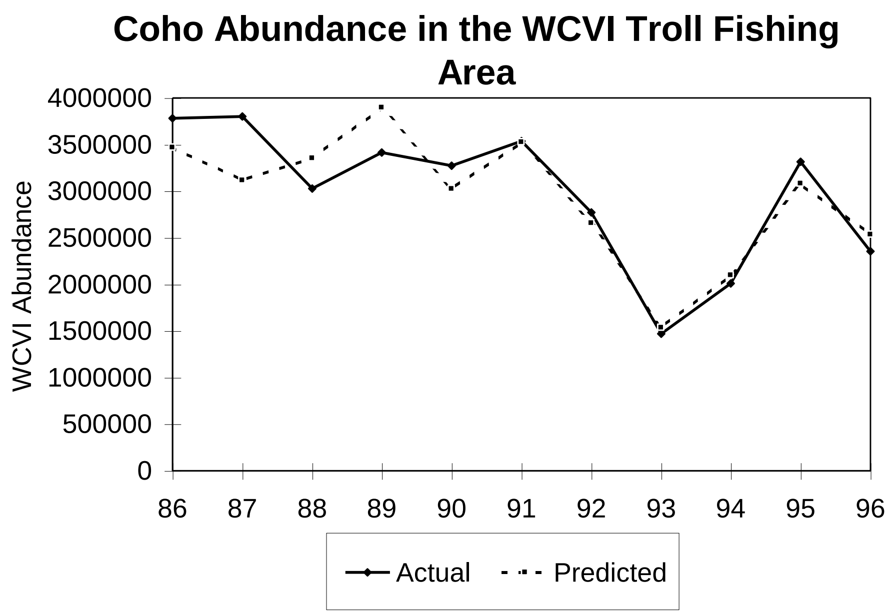

Figure 8. Predicted versus actual abundance of coho in the WCVI troll fishing area.

5. Conclusions

1) The marine survival of Strait of Georgia coho in 1997, as indicated by the Quinsam River hatchery stock, is expected to continue to be low at 0.019. Wild stocks will likely have a slightly higher survival rate but will also be low relative to 1980's levels.

2) The distribution of Strait of Georgia coho in 1997 is expected to be similar to 1995 and 1996 with a high proportion of the expected catch (under recent fishing patterns) occurring off the west coast of Vancouver Island and a very low proportion occurring in the Strait of Georgia.

3) The abundance of coho in the WCVI troll fishery in 1997 is estimated at 2,753,000. This is slightly less than the 1996 forecast of 2.85 million but greater than the actual 1996 return of 2.35 million. Caution should be exercised in using this forecast, however, since it is very sensitive to the marine survival rate forecast which may be optimistic as it has been in recent years.

4) All of the forecasts described above have a high degree of variability in their defining relationships. They should therefore be used to characterize the return and not to develop precise management regimes around their mid-points.

6. Acknowledgments

The authour would like to thank D. Blackbourn for providing lighthouse salinity and catch distribution data and analyses.

7. References

Kadowaki, R., B. Holtby, K. Simpson, and D. Blackbourn. 1996. An update of assessment information for Strait of Georgia coho salmon stocks with 1996 forecasts and advice on setting an exploitation rate target. PSARC Working Paper S96-11.

Appendix Table 1. Quinsam River hatchery CWTs released, total smolts released, age 2 and age 3 observed, estimated (corrected for fishery catch sample rate) and expanded (corrected for fishery catch sample rate and the mark rate at release) recoveries for brood years 1974-1994.

Brood Year	CWTs Released	Total Released	Observed Age 2	Observed Age 3	Estimated Age 2	Estimated Age 3	Expanded Age 2	Expanded Age 3
1974	160177	1439951	499	2196	2592	10023	23483	83510
1975	73442	661667	217	1647	2114	6963	19047	62729
1976	139968	537382	323	2395	2608	9573	7941	34267
1977	168286	1331237	837	5080	1993	15750	15026	117791
1978	226186	1382865	1596	4208	1975	11982	15746	86884
1979	280127	985767	2651	5573	2881	12863	12742	45091
1980	76237	1275830	474	1486	513	4567	8090	72864
1981	279799	948180	850	5991	910	14504	2815	47845
1982	317306	1174047	3269	10092	3445	27580	11179	92770
1983	220929	1853852	1421	6466	1530	17903	14824	126507
1984	77380	1201640	942	2001	968	6486	15029	100763
1985	42176	1287066	851	1236	928	3358	28269	102399
1986	192294	1347697	2793	3470	2821	14762	25055	136990
1987	39362	1057725	358	1022	791	3041	21247	81708
1988	39466	1172118	228	570	297	1641	8832	48743
1989	39400	1176616	214	605	251	2283	7479	68166
1990	39411	1220201	224	355	233	1368	7212	42393
1991	42470	1224754	224	242	315	963	9023	27631
1992	43742	1128936	225	550	350	1030	8994	26749
1993	38947	1193987	.	.	129	365	3938	11188