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Forecast for southern British Columbia coho salmon in 2002

Prévisions pour le saumon coho du sud de la Colombie-Britannique pour 2002

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Abstract

This research paper documents forecasts of marine survival, abundance and distribution for the coho salmon of southern British Columbia (Fraser River system, Strait of Georgia, and west Vancouver Island) for return year 2002.

Marine survival

Recommendations for the marine survival forecast for the five hatchery indicators and two wild coho indicators are:

Indicator	Recommended Model	Predicted Survival in 2002 (50% CI)	Change (2002 forecast minus 2001 observed S)
Big Qualicum	LLY	0.021 (0.014 - 0.032)	0
Quinsam	3YRA	0.013 (0.010 - 0.018)	-0.004
Chilliwack	RAT3	0.035 (0.025 - 0.049)	-0.015
Inch	3YRA	0.026 (0.013 - 0.050)	-0.036
Black	3YRA	0.030 (0.021 - 0.042)	-0.043
Robertson:	Sibling	0.031 (0.019 - 0.049)	-0.065
Carnation	Euphausiid	0.040 (0.032 - 0.050)	-0.018

For the 1999 brood in the Strait of Georgia, time series forecasts are for survivals to remain about the same (Vancouver Island hatcheries) or decrease (Lower Fraser hatcheries and Black Creek, the wild indicator on Vancouver Island). Trawl surveys in 2001 suggest that the four hatchery indicators will have a mean survival similar to the 2001 return. These survivals can be characterised as poor, relative to survivals experienced 10 to 20 years ago and in terms of the low exploitations that are necessary at these survivals for wild populations to sustain themselves.

Survival forecasts have been less accurate for west Vancouver Island indicator stocks. Until recently, Robertson Hatchery was the only indicator stock, where survival and exploitation measurements were taken. This year a sibling model predicted a survival of 3.1%, much less than the 9.6% last year but a time series model predicted the same survival as last year. Both have performed about the same in the past. We chose the sibling forecast because it is more conservative and because the second indicator, the wild Carnation Creek stock, has a similar forecast of 4%. The Carnation forecast is based on the abundance of an euphausiid prey species in Barkley Sound. This forecast also represents a decrease: survival in 2001 was 5.8%.

Abundance

Forecasting abundance of coastal stocks is highly problematic, particularly in the present regime of low exploitation. The forecasts have been sufficiently poor that we have chosen to discontinue them. Another method may be developed in the future. The forecast total abundance of Thompson River watershed coho uses time series analysis of measured abundances (direct estimates of catch and escapement) and it is still feasible. The forecast for 2002 is ~25,000, which is about half the observed abundance in 2001. It does represent a forecasted increase over the 1999 brood abundance of 18,700, however. The escapement in 2001 was the largest since 1989 and escapements in 2000 and 1999 were larger than brood year escapements. Greater proportions of fish that are surviving to maturity are returning to spawn because of the significant reductions in fishing pressure. Thus, assuming marine survivals and fishing pressures remain low, the outlook for Thompson and other interior Fraser coho is for slow but gradual improvement.

Distribution

In the hypothetical circumstance of historical patterns of fishing, the predicted proportion of catch inside the Strait of Georgia would be 0.35 (50% CI: 0.27–0.45), which can be characterized as a moderate outside distribution. A strong inside year is highly unlikely.

<u>Résumé</u>

Le présent document de recherche établit les prévisions de la survie en mer, de l'abondance et de la distribution du saumon coho du sud de la Colombie-Britannique (réseau du Fraser, détroit de Georgia et côte ouest de l'île de Vancouver) pour l'année de remonte 2002.

Survie en mer

Voici les recommandations au titre des prévisions de la survie en mer pour les cinq indicateurs des cohos d'écloserie et les deux indicateurs des cohos sauvages :

Indicateur	Modèle recommandé	Taux de survie prédit en 2002 (IC à 50 %)		Changement (previsions 2002 moins S observé en 2001)
Big Qualicum	LLY	0,021	(0,014 – 0,032)	0
Quinsam	3YRA	0,013	(0,010 – 0,018)	-0,004
Chilliwack	RAT3	0,035	(0,025 – 0,049)	-0,015
Inch	3YRA	0,026	(0,013 – 0,050)	-0,036
Black	3YRA	0,030	(0,021 – 0,042)	-0,043
Robertson	Jumelles	0,031	(0,019 – 0,049)	-0,065
Carnation	Euphausiacés	0,040	(0,032 – 0,050)	-0,018

Pour les jeunes nés en 1999 dans les affluents du détroit de Georgia, les prévisions en série chronologique vont dans le sens leur taux de survie restera presque pareil (écloseries de l'île de Vancouver) ou diminuera (écloseries du bas Fraser et ruisseau Black, indicateur du coho sauvage dans l'île de Vancouver). Les résultats des relevés au chalut effectués en 2001 donnent à penser que les taux de survie moyen des quatre stocks indicateurs de cohos d'écloseries seront semblables à ceux de la remonte de 2001. Ces taux de survie sont faibles par rapport à ceux observés il y a 10 à 20 ans en terme des faibles taux d'exploitation requis pour assurer la durabilité de ces populations.

Les prévisions des taux de survie des stocks indicateurs de l'ouest de l'île de Vancouver sont moins précises. Jusqu'à récemment, le stock de l'écloserie du ruisseau Robertson était le seul stock indicateur pour lequel les taux de survie et d'exploitation étaient quantifiés. D'après un modèle des espèces jumelles, le taux de survie cette année s'élèvera à 3,1 %, ce qui est nettement moindre que le taux de 9,6 % de l'an dernier, bien qu'un modèle en série chronologique ait donné ce même taux. Fait intéressant, les deux modèles ont donné des résultats semblables par le passé. Nous avons toutefois choisi la prévision issue du modèle des espèces jumelles parce qu'elle est plus prudente et que le second indicateur, le stock sauvage du ruisseau Carnation, montrait une prévision du taux de survie semblable de 4 %. La prévision pour le ruisseau Carnation, qui repose sur l'abondance d'une espèce-proie d'euphausiacés dans la baie Barkley, est à la baisse, le taux de survie en 2001 se chiffrant à 5,8 %.

Abondance

La prévision de l'abondance des stocks côtiers est hautement problématique, en particulier à la lumière du régime actuel de faible exploitation. Les prévisions étaient tellement mauvaises que nous avons donc décidé de ne plus en faire. Une autre méthode sera peut-être élaborée à l'avenir. La prévision de l'abondance totale du coho du bassin versant de la rivière Thompson reposant sur une analyse en série chronologique des abondances quantifiées (estimations directes des prises et des échappées), il est encore possible de la faire. La prévision de l'abondance en 2002 se chiffre à environ 25 000 cohos, ce qui correspond à environ la moitié de l'abondance observée en 2001 et constitue une augmentation par rapport à l'abondance des jeunes de l'année en 1999, chiffrée à 18 700 cohos. L'échappée en 2001 était la plus forte depuis 1989, tandis que les échappées en 2000 et 1999 étaient plus abondantes que les échappées des jeunes de l'année. De plus fortes proportions de saumons qui survivent jusqu'à la maturité reviennent frayer à cause de fortes réductions de la pression par pêche. Par conséquent, si l'on suppose que le taux de survie en mer et la pression par pêche demeurent faibles, les perspectives pour le coho de la Thompson et d'autres cours d'eau du haut Fraser vont dans le sens d'une amélioration lente quoique graduelle.

Distribution
Dans l'hypothèse que les tendances historiques de la pêche seront les mêmes, la proportion prédite des prises dans le détroit de Georgia s'élèverait à 0,35 (I.C. à 50 % : 0,27–0,45), qui peut être caractérisée comme une distribution modérée dans les eaux extérieures. Il est hautement improbable que les prises seront fortes dans les eaux intérieures.

1. Introduction

This Research Paper presents forecasts of the marine survival rate, the ocean distribution and the ocean abundance of southern British Columbia (sBC) coho in 2002. The methods we used in developing the forecasts of marine survival rate and ocean distribution are similar to those used in previous working papers (Simpson et al. 2001a; Holtby et al. 1999, 2000; Kadowaki and Holtby 1998; Kadowaki 1997; Kadowaki et al. 1996). One major difference is that we have not continued the forecasts of abundance for the Strait of Georgia and west coast of Vancouver Island (wVI) aggregates. We concluded that the forecast model was too poor to be useful. We have continued the interior Fraser abundance forecast, however. This uses a different method, which is not feasible on the coast. This report also includes a more thorough utilization of coho catch data being collected from trawl surveys in the Strait of Georgia and a new analysis to estimate fishing mortality of indicator stocks.

2. Data Sources and Treatments

2.1 Estimates of Marine Fishing Mortality

In 2001, marine fisheries for coho in BC continued to be limited in order to conserve weak stocks of concern, primarily those originating from the Thompson River. There were no commercial fisheries either directed at coho or allowing retention of coho in the Strait of Georgia and wVI. However, there were sport fisheries allowing retention of hatchery marked coho in certain areas and times in the straits of Georgia and Juan de Fuca and on wVI. Hatchery marked coho had their adipose fin removed at the hatchery ('Ad-clips'). A retention of two marked coho was allowed in offshore areas of wVI (Areas 123-127), in Area 26 and, later in the season, in Areas 19 and 20. One unmarked coho was allowed in the daily catch in inshore waters of Areas 23, 24, 25 and 27. That daily allowed catch was two coho in these inshore areas except in Area 23 where the limit was increased to four in the summer, i.e. the limit was four with only one allowed to be unmarked. Particularly in terminal areas, such as Barkley Sound and Big Qualicum, the sport fisheries observed in 2001 were larger, both in terms of catch and effort, than the previous three years, reflecting a response to both increased fishing opportunity and increased abundance of coho. Increased sport effort was also observed in Juan de Fuca Strait, which was largely in response to Fraser pink abundance. However, time and area closures were used in these fisheries to minimize impact on wild coho stocks.

Since the 1998 initiation of coho non-retention in BC fisheries, estimating mortality rate in BC fisheries has become unreliable with fewer coded wire tag (CWT) recoveries. There are problems associated with determining encounter rates and hooking mortality as well as estimating the stock composition of encounters. Selective mark-only fisheries further complicate the situation (Pacific Salmon Commission 2002). Over the past three years, post-season estimates of total mortality of Thompson coho were derived from estimating the stock composition of encounters through genetic analysis of sampled coho encountered in various fisheries. However, 2001 estimates are not available in time for March pre-season forecasting. Instead, we used an approach that relies on historical estimates of CWT recoveries and effort. The same approach was used for pre-season planning of fisheries in 2001.

Historical exploitation rates estimated from CWT recoveries in various commercial and sport fisheries were averaged for each indicator stock. The indicator stocks were Big Qualicum, Quinsam, Inch and Chilliwack hatcheries and Black Creek for the Georgia Basin, Robertson Creek hatchery for wVI and the Eagle and Salmon rivers for the Thompson. Historical effort and exploitation rate data provided an average exploitation rate/unit effort for a given base period for each fishery-indicator combination. Observed effort in 2001 was then used to estimate fishery impacts assuming a proportional relationship between effort and exploitation rate and assuming standard release mortality rates. In commercial fisheries, additional scalars were used to account for changes in fleet size, gear efficiency and selective fishing practices (e.g. coho avoidance and/or increased survival of bycatch). These scalars were subjectively determined by a fisheries manager (pers. comm., L. Hop Wo, Salmon Stock Assessment Section, South Coast Area, Nanaimo). For US fisheries, Alaskan exploitation rate was assumed to be the average observed during the 1987-1997 period and southern US fisheries were assumed to be half the average observed during the same period.

2.1.1 Commercial Fisheries

The base period used depended on available effort data and CWT data. For commercial fisheries, the base period of historical exploitation rate and effort data was the return years 1987-1997. For net fisheries, the measure of effort was days open. The exploitation rate in a given month and year was divided by the effort (days open) observed in the fishery for that month. All the monthly observations were then averaged across the base period to estimate the average exploitation rate/day in each fishery for a given month. Mortality rates in 2001 net fisheries were estimated by the following formula for each fishery-month combination:

$$Mortality_{2001} = \left(\overline{ER/Effort} \right)_{87-97} \times Effort_{2001} \times Fleet\,/\,Gear\ Scalar \times Release\ Mortality\ Scalar$$

Eqn. 1

where effort is measured in days open, and the Fleet/Gear scalar is based on a subjective assessment by a fisheries manager to account for fleet changes and selective fishing practices. The release mortality scalar was assumed to be 60% for gillnet fisheries and 25% for seine net fisheries. The estimated mortality rates in all fishery-month combinations were summed to estimate total exploitation rate for 2001 in net fisheries for each indicator stock.

For troll fisheries, where effort data are less reliable, the average exploitation rate/month was calculated for the fishery-indicator combination. Mortality rates in 2001 were estimated by the following formula:

$$Mortality_{2001} = \left(\overline{ER/Effort}\right)_{87-97} \times Effort_{2001} \times Fleet/Gear\,Scalar \times Target\,Scalar \times Release\,Mortality\,Scalar$$

Eqn. 2

where effort is measured by percentage of month open, and the Fleet/Gear scalar and Target scalars are determined by subjective assessment by a fisheries manager to account for the effects of downsizing the fleet size and avoiding coho, respectively. The release mortality scalar was assumed to be 15% for troll fisheries.

2.1.2 Recreational Fisheries

The base period used for sport fisheries was from 1981 to 1997, except for Thompson stocks, for which data were limited to the 1987-1997 return years. Average exploitation rates for the base period were calculated for each indicator-fishery combination on an annual basis. Annual averages were calculated because historical recoveries in any month were relatively rare. It was assumed that before mandatory non-retention in 1998, catch was a reasonable indicator of encounters. In 2001, encounters (catch and release) were estimated using creel surveys which also estimate effort (boat trips). The basic equation used to estimate exploitation rate (some coho retention allowed) in recreational fisheries was:

$$ER_{2001} = \overline{ER}_{87-97} \times Relative\ Effort_{2001/87-97} \times Hatchery\ Stock\ Release\ Mortality\ Scalar$$

Eqn. 3

To scale historic average exploitation rates, the relative change in effort (boat trips) from the base period to 2001 was calculated for each catch region by the following ratio:

$$Relative\ Effort_{2001/87-97} = \frac{Effort_{2001}}{\overline{Effort}_{87-97}}$$

Eqn. 4

where effort is measured in boat-days. Sport fisheries allowed for coho retention during some times and areas, but there were still encounters of coho in non-directed fisheries. The only area that appeared to avoid coho during periods of non-retention was in northern Strait of Georgia (GSPTN). For that reason, relative effort was further scaled in GSPTN according to periods of coho non-retention and retention so that:

$$GSPTN\ Relative\ Effort_{2001/87-97} = \frac{(Effort\ directed)_{2001} + (Effort\ non-directed)_{2001}}{\overline{Effort}_{87-97}}$$

Eqn. 5

where 'effort' in non-directed fisheries in GSPTN was estimated by correcting for the coho encounter rate so that:

$$GSPTN\ Effort, nd_{2001} = \left(\frac{(Coho\ encounters\ / boat\ trips)_{nd, 2001}}{(Coho\ encounters\ / boat\ trips)_{d, 2001}} \right) \times Boat\ trips_{nd, 2001}$$

Eqn. 6

where *nd* and *d* refer to non-directed and directed fisheries, respectively. For wild indicator stocks the release mortality scalar was assumed to be 10%. For hatchery indicator stocks, the release mortality scalar was assumed to be 10% during non-retention periods, but was scaled higher to account for retention (selective mark fishery) periods. To account for retention periods, the scalar was adjusted according to the amount of total effort observed in non-directed and directed (SMF) fisheries. In non-directed fisheries, release mortality was assumed to be 10% and in selective mark-only fisheries it was assumed that all encountered hatchery fish were retained:

$$Hatchery\ Stock\ Release\ Mortality\ Scalar = \left(\frac{Effort\ non-directed_{2001}}{Total\ Effort_{2001}} \right) \times 0.1 + \left(\frac{Effort\ directed_{2001}}{Total\ Effort_{2001}} \right)$$

Eqn. 7

Table 1 shows estimates of marine exploitation rates of southern BC and Interior Fraser indicator stocks in 2001. Note that these are displayed as point estimates and therefore do not reflect the range of uncertainty in the data. Also note that the total exploitation estimates do not include mortalities in freshwater sport or First Nations fisheries. Freshwater sport mortalities were calculated separately from creel data (Sect. 2.3).

The catch and release mortality of Robertson Hatchery coho in the directed Area 23 sport fishery was calculated from creel data provided by K. Hein (Salmon Stock Assessment, South Coast Area, Nanaimo). This was done by assuming that all encounters of marked and tagged coho in the Area 23 sport fishery were Robertson-origin coho. Although obviously wrong, the over-estimate is probably very small based on historic recoveries of CWT-ad coho (coho tagged with CWTs and marked with an adipose fin clip) from other sources. Some marked coho were released in the fishery. The ratio of CWT-ad coho to the total number of adipose clipped coho in the Robertson escapement was used to estimate how many of these marked coho releases had tags and a release mortality of 10% was applied to that CWT-ad release estimate. Mortalities in other fisheries were calculated as explained above.

An exploitation of 5% was assumed for Carnation coho in 2001. Retention of one unmarked coho per day was allowed for part of the season in Area 23 but a large proportion of the effort was in Alberni Canal, east of Carnation Creek, which is near Bamfield. This effort was largely directed toward Robertson Hatchery coho (a retention of three marked coho was allowed in the latter part of the season). The exploitation of unmarked Robertson Hatchery coho was about 7%, based on an analysis of that hatchery's tagged but unmarked (CWT-only) release group. The analysis included an allowance of 10% mortality of released fish.

2.2 Interior Fraser including the Thompson River

The interior Fraser is defined as the Fraser River watershed above Hells Gate and includes the Thompson River, the largest watershed in the Fraser River system. Coho originate in four sub-regions in the interior Fraser (Irvine et al. 2000):

1. South Thompson – the South Thompson R. and its tributaries;
2. North Thompson – the North Thompson R. and its tributaries;
3. Lower Thompson – the mainstem Thompson R. and tributaries downstream from the confluence of the North and South Thompson rivers, including the Nicola watershed; and
4. Fraser/non-Thompson – the Fraser R. and tributaries upstream of the Fraser Canyon excluding the Thompson.

An 'abundance' time series was derived from an escapement time series (Irvine et al. 1999a,b; 2000) that consists chiefly of spawner estimates made during visual surveys. We have been able to reliably reconstruct the escapement time series for the North and South Thompson systems as far back as 1975 and Lower Thompson streams back to 1984. Many Fraser/non-Thompson streams were not reliably assessed for coho escapement prior to 1998.[1] The time series includes all of the streams within each sub-region where there were at least two annual estimates of escapement that we feel reflect changing patterns in fish abundance and includes wild and enhanced coho (Table 2). Catch and abundance (i.e. catch plus escapement including fish taken for brood stock) were estimated from the escapement time series for each censused stream using a time series of exploitation rates (Table 3).

The time series of exploitation rates for the Thompson were generated from the Mark Recovery Program (MRP) CWT recoveries for a variety of releases from 1986 to 1997 and the escapement estimates. Estimates prior to 1986 were the arithmetic average of measured values from 1986 to 1996. Regulatory changes to salmon fisheries, beginning in 1998, saw most fisheries become non-retention for coho. Therefore, few coho were sampled for CWTs from which exploitation could be estimated. Alternatively, exploitation rates for 1998 through 2000 were estimated through the application of stock composition estimates developed from a DNA-based approach to estimates of coho killed in fisheries (Irvine et al. 2000). Using this method, the estimated exploitation rate in 2000 was 3.4%. Canadian exploitation of Thompson coho is estimated to have been 1.1% using this DNA approach. Using the effort adjustment to historic exploitation rate approach, described above, the estimate is 2.1%. Assuming the exploitation of Thompson coho in the US (excluding Alaska) in 2001 was equal to a scaled historic average of 5.9%, the DNA and effort estimates of total exploitation are 7.0% and 8.0%, respectively. We calculated the abundance of Thompson coho in 2001 using the 8% estimate.

2.3 Strait of Georgia, Lower Fraser and West Vancouver Island Hatcheries

Five hatchery stocks are used in forecasting survival of south coast coho: Robertson (wVI), Quinsam and Big Qualicum (east coast of Vancouver Is., eVI), and Inch and Chilliwack (lower Fraser). Two wild stocks are used: Black (eVI) and Carnation (wVI). Hatchery survival rate estimates are made only for CWT-ad coho. Hatchery releases of coded wire tagged smolts since 1997 have also included unmarked (CWT-only) groups. Virtually all the rest of hatchery production was marked with a pelvic fin clip in 1997 (except at Quinsam and Robertson hatcheries) and with an adipose clip since then (Simpson et al. 2001b). This mass marking was to prepare for possible selective mark fisheries, which allow significant protection to wild stocks while allowing exploitation of enhanced stocks. All smolts captured at the Black and Carnation creek fences are tagged (only starting in 2001 at Carnation). We stopped fin clipping the Black Creek run in 1998 in preparation for selective mark fisheries and Carnation Creek coho are not marked either.

We used the hatchery releases of CWT-ad smolts that are recorded in the MRP database maintained at the Pacific Biological Station in Nanaimo, BC. Hatchery escapement data were provided by the Habitat and Enhancement Branch (pers. comm. S. Lehmann, HEB Vancouver; G. Bonnell, South Coast Area, Victoria). Smolt release and escapement data for Black Creek are collected by us (KS; SB) and Carnation Creek data are provided by the BC Ministry of Forests (pers. comm. P. Tschaplinski, Victoria). Catch and release data for the freshwater sport fishery in Somass River (Robertson Hatchery) were provided by D. Lewis (Salmon Stock Assessment, Central Coast Area, Campbell River). T. Carter (Salmon Stock Assessment, South Coast Area, Nanaimo) provided the same for Big Qualicum River and S. Grant (Stock Assessment, Lower Fraser Area, Delta) provided creel data for Nicomen Slough (Inch Hatchery) and Chilliwack/Vedder River. Data for each indicator are shown in Table 4.

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[1] To address the issue of incomplete escapement estimates to Fraser/non-Thompson streams, there now is improved coverage during annual escapement surveys, and there is a coho sampling program in the Fraser Canyon using a fishwheel. DNA samples are taken at the fishwheel to identify stocks.

2.3.1 Robertson Creek Hatchery

Two categories of questions occur at Robertson Hatchery and other wild and hatchery indicators. First, there is a question of how accurately the stock represents an aggregate of stocks, in this case wVI. The second question is about measurement errors. With the heavy reliance on Robertson Hatchery stocks for assessments of wVI chinook and coho and with increasingly accurate comparative data available from the counter facility at Stamp Falls (downstream from Robertson), Robertson data are being scrutinized more than other hatchery data and some inaccuracies are more apparent. For example, there are discrepancies between mark rates of coho smolts released at Robertson, of subsequent returns passing through Stamp Falls, and of coho arriving at Robertson. This was discussed by Dobson et al. (2000). Some of these discrepancies are not unique to Robertson (Schnute et al. 1990).

There are three data collection problems known to exist at Robertson, none of which is unique to this facility. Up until 2000, jacks were easily able to escape being brailed from the attraction pond into the holding pond. In 2000, the mesh size was reduced on the crowder panels in the attraction pond, which are used to concentrate the fish for capture. However, some still escape around the panels during the operation. Prevention of these escapes will be costly. This introduces an error, which may affect sibling forecasts of adult returns the following year. Secondly, jacks and adults are free to leave the attraction pond before being brailed into the holding pond. How many remain to be captured may depend on difficult to document factors such as maturity and density in the pond. Some hatchery progeny do not enter the hatchery facility at all. This is a universal problem that will probably never be fully addressed. Finally, although the objective is to process all time segments of the escapement, some coho enter after the last sort. This was stated by Simpson et al. (2001a) to be a potentially serious problem at Robertson Hatchery. After reviewing this with hatchery staff and other HEB staff, we have concluded it is probably not as serious as feared. When the escapement is large the number of unprocessed late coho is larger (pers. comm., G. Rasmussen, OCS, South Coast Area, Port Alberni). However, it is not clear whether the proportion that is missed is larger when runs are larger.

Thinking the last problem may be serious, last year we calculated an alternative data set of returns based on the coho counts at Stamp Falls (Simpson et al. 2001a). We estimated total returns to Stamp Falls, using the Stamp Falls counts plus the expanded marine catch of Robertson coded wire tagged coho. Counts are available since 1986. A new time series of Robertson survivals was generated by using Robertson smolt releases and estimating the Robertson return as a constant 85% of the Stamp Falls count. This was the composition in 2000 (virtually all Robertson coho were adipose clipped and could be identified at the counter). The tenability of this constant proportion assumption will become clearer with more years of monitoring at the falls in conjunction with mass marking. The preliminary estimate of the proportion of hatchery coho at Stamp Falls in 2001 was 83%, which included an estimate of the CWT-only coho. The two time series have much the same trends in survival (Simpson et al. 2001a). Only once, from 1992 to 1993, was there a difference in trend direction (the survival estimate using hatchery escapements increased but the Stamp Falls data indicated no change). The correlation in survivals to 2000 using the two data sets was 0.94**.[2] The similarity in the time series and subsequent clarification on the hatchery procedures allows us to continue using hatchery escapement data, at least until we have more years of counts at Stamp Falls of mass marked Robertson coho.

2.4 Salinity Data

The proportion of coho residing in the Strait of Georgia in their last ocean year is forecast using a relationship with salinities in the Strait. Salinity data for the Chrome Island and Sisters Islet lighthouses in the Strait of Georgia were obtained from R. Perkin, Institute of Ocean Sciences, Sidney, BC.

3. Forecasting Models and Retrospective Analysis of Predictive Power

3.1 Forecasting Models

3.1.1 Time Series

In this document, we forecast catch distribution (p_{inside}), marine survival rates (*s*), and abundance (*A*), the latter only for Thompson stocks in the interior Fraser area. Four quasi-time series models are used in one procedure to forecast survivals and abundances. In each model the variable being forecast (v_t) is first transformed so that

$$Z_t = \Im(v_t) \qquad \text{Eqn. 8}$$

The Log transformation was used for abundance of Thompson coho. The Logit transformation was applied to survivals and it was also used to transform p_{inside} values for the regression forecast used for that variable.[3] The four models can then be described as follows:

Mnemonic	Model	Equation
LLY ("Like Last Year")	$Z_{t+1} = Z_t + \varepsilon_t$	Eqn. 9

[2] * refers to .01 ≤ p < .05; ** refers to p < .01

[3] The Logit transformation, $Z_t = \ln\left(\frac{v_t}{1-v_t}\right)$, stabilizes variances and puts survival or p_{inside} measures on the zero to infinity scale, which is necessary for regressing with the like-scaled salinity variable and for assuming normal errors in the time series analyses. It also straightens the salinity: p_{inside} relation.

Mnemonic	Model	Equation
3YRA (3-year average)	$Z_{t+1} = \frac{\sum_{k=t-2,t} Z_k}{3} + \varepsilon_t$	Eqn. 10
RAT1 (1 year trend)	$Z_{t+1} = \frac{Z_t^2}{Z_{t-1}} + \varepsilon_t$	Eqn. 11
RAT3 (average 3-year trend)	$Z_{t+1} = \frac{\sum_{k=t-2,t} Z_k / Z_{k-1}}{3} Z_t + \varepsilon_t$	Eqn. 12

For each model, we assume that the error term is normally distributed $\left(\varepsilon \sim N(0,\sigma^2)\right)$ and is independent of time. For estimating uncertainty in the forecast value (Z_{t+1}), an estimate of σ^2 was obtained for the distribution of observed minus predicted for years $1 \ldots t$.

The differences between the four models are summarized in the following table:

		Years used in prediction	
		1	3 (≈ 1 cycle)
Allows projection of trends?	NO	LLY	3YRA
	YES	RAT1	RAT3

3.1.2 Sibling Regressions

Marine survival rates were also predicted using a “sibling-regression” model, where the total return of age x.1 fish in year t ($R_{t,x.1}$) is predicted from the observed x.0 male escapement in the previous year ($R_{t-1,x.0}$, ‘jacks’):

$$\ln R_{t,x.1} = b \ln R_{t-1,x.0} + a \qquad \text{Eqn. 13}$$

Predicted survival (s_{smolt}) was then calculated by dividing the predicted age x.1 return by the number of smolts released (N_{smolt}).

3.1.3 Euphausiid - Based Forecast for wVI Coho

This year's forecast reflects an evolution of the euphausiid-based forecasts presented in Simpson et al. (2001a, 2000). The new approach is based on testing directly the null hypothesis that feeding conditions during the early marine phase and/or smolt abundance have no effect on marine survival rate of Carnation Creek coho. In earlier years, survival rate was the dependent variable in the forecasting equation. This has been decomposed into its components (number of returning adults, number of out-migrating smolts) so that the effect of smolt number can be tested, and the confounding of error in the two variables can be separated. The equation we used was:

$$ln\, R_{t,x.1} = a \bullet ln\, E_{t-1} + b \bullet ln\, S_{t-1} + c \qquad \text{Eqn. 14}$$

where $R_{t,x.1}$ is number of returning adults, E_{t-1} is euphausiid abundance the previous year when they were smolts, S_{t-1} is number of smolts and c is the intercept. Euphausiid abundance (no. • m^{-2}) and biomass (mg dry mass • m^{-2}) estimates were for 9 – 12 mm *Thysanoessa spinifera*, the euphausiid that coho smolts consume during their first summer on the coasts of Oregon (Petersen et al. 1982) and wVI (Tanasichuk, unpubl. res.). The euphausiid data come from a zooplankton monitoring program, which began in 1991. Collection and processing protocols for euphausiids are fully described in Tanasichuk (1998).

3.1.4 Strait of Georgia CPUE Forecast

Surveys for juvenile salmon in the Strait of Georgia have been conducted in late June/July for the past five years, aboard the CCGS W.E. Ricker. As noted in Beamish et al. (2000a), the survey design (Figure 1) has been constant during this time, as has the gear used: a modified mid-water trawl (approximate dimensions: 14 x 36 x 200 m) towed at 4-5 knots. The sets (10-12 per day) are performed according to a stratified random design at 15 m depth increments (i.e., head-rope at surface, 15, 30, 45 or 60 m) with 50% of the effort weighted to surface tows. Upon retrieval of the catch, the various species are sorted by experienced DFO personnel and counted. All coho are examined for presence or absence of the adipose fin (or other fin clips) as well as scanned for CWTs. Sub-samples of the catch are then processed (morphology, otoliths/scale collection, diet analysis, etc). When a positive CWT response is obtained, the head is removed, bagged with an identifying tag and stored until the tag is recovered and decoded. Net opening size, depth, speed of tow and water temperature at net depth are recorded for each set. Further references are Beamish and Folkes (1998) and Beamish et al. (2000b).

There is a summary of the annual catches of marked and unmarked coho in Table 5. To forecast coho survival for 2002, the catch per unit effort (CPUE) for clipped (hatchery) and non-clipped (hatchery plus wild) salmon were calculated. For each set, the number of coho without adipose fins was divided by the total clip percentage for Strait of Georgia hatchery coho, as found in the MRP database, to obtain the total number of hatchery fish in that set:

Hatchery coho per set = (Number of clipped coho per set) ÷ (proportion of releases clipped)

Eqn. 15

The remainder of the catch for each set was then assigned as the 'non-hatchery' component. The CPUE was then calculated by dividing the total hatchery (or non-hatchery or total) catch for the survey by the total number of hours fished in that survey, to obtain a catch per hour value:

$$CPUE = \sum (hatchery\ coho) \div (\sum(minutes\ fished)/60\ min) \quad \text{Eqn. 16}$$

Hatchery and Black Creek survival data were obtained from Simpson et al. (2001b). The CPUE for hatchery fish was then regressed against the mean smolt-adult survival of the four hatchery indicators (Chilliwack, Inch, Big Qualicum and Quinsam). The remaining unmarked catch, consisting of wild coho and some unaccounted for enhanced coho, e.g. from fry releases and from US hatcheries, were used to calculate a 'wild' CPUE. The survival of Black Creek coho was regressed on 'wild' CPUE.

3.1.5 Salinity Regressions

Coho originating in systems around the Strait of Georgia are largely caught in the Strait or on the west coast of Vancouver Island but the proportion caught in each area varies between years (Kadowaki 1997; Simpson et al. 2000). The measure of distribution we use is the proportion of the catch of hatchery indicator stocks taken in fisheries wholly within the Strait of Georgia (p_{inside}). We emphasize that forecasts of distribution are actually forecasts of catch distribution assuming average historic patterns of effort distribution. However, coho fisheries have been highly restricted in the inside waters of sBC since 1997. Consequently, there has been no estimate of p_{inside} since 1997 and the time series models that were developed in 1998 cannot be applied (Kadowaki and Holtby 1998). However, we note that the salinity model outperformed the time-series models by a large margin. This model predicts the proportion of catch taken in the Strait if pre-1997 fishing regimes were in place and this proportion is now used as an index of inside distribution.

Surface salinity's measured at Sisters and Chrome island lighthouses in the year of return are positively correlated with p_{inside}. These islands are in the central Strait of Georgia. Salinity in February of the year of return is the best predictor of p_{inside} up to the time of the forecast. March is better yet (pers. comm., D. Blackbourn, 562 Bradley St., Nanaimo). Kadowaki (1997) averaged the daily February values from each lighthouse and then averaged the two means. Kadowaki et al. (1996) and Kadowaki and Holtby (1998) just used the mean February salinity at Chrome Island. Holtby et al. (2000) reverted to the average of Chrome and Sisters islands. Within and between lighthouse variances are typically not large over the month and the differences between the predictions are small and of no practical significance.

The regression model is:

$$Logit(p_{inside}) = bS + a \quad \text{Eqn. 17}$$

where S is the mean of the monthly mean salinities at Chrome and Sisters islands for February of the year of adult return. Confidence limits around the sibling and salinity forecasts were determined using linear regression analysis.

3.2 Retrospective Analyses

To compare the performance of the forecast models we computed for a common period of years, $k = 1,n$ both the Root Mean Square Error (*RMSE*):

$$RMSE = \sqrt{\frac{\sum_{k=1}^{n}(v_{observed,k} - v_{predicted,k})^2}{n}} \qquad \text{Eqn. 18}$$

and the Mean Absolute Deviation (*MAD*):

$$MAD = \frac{\sum_{k=1}^{n}\left|(v_{observed,k} - v_{predicted,k})\right|}{n} \qquad \text{Eqn. 19}$$

Note that this calculation is performed in the variable space and not in the transformed space (Eqn. 8).

4. Forecasts of Marine Survival

4.1 Forecast Performance in 2001

Estimates of marine survival in 2001 are shown in the five hatchery indicators and two wild indicators. Marine survival in 2000 and 2001 are compared in the following table.

	Marine Survival		
	2000	2001	Relative Change
Quinsam	0.017	0.017	1%
Black	0.023	0.073	217%
Big Qualicum	0.020	0.021	5%
Chilliwack	0.023	0.050	117%
Inch	0.014	0.062	343%
Average StG-Fr	0.019	0.045	130%
Robertson	0.103	0.096	-7%
Carnation	0.048	0.058	21%

The survival of the two wVI indicator stocks changed little from 2000. On the Strait of Georgia side of Vancouver Island, both hatchery indicator stocks continued to survive poorly, remaining near 2% in both years. Conversely, the survival of Black Creek coho dramatically improved from 2.3% in 2000 to 7.3% in 2001. The lower Fraser indicator stocks also survived much better, more than doubling their survivals to 5.0% and 6.2%. Overall, survivals continued to improve from the nadir in 1999.

The performance of the 2001 forecasts (Simpson et al. 2001a) is summarized in the following table, in Table 6 and Figure 2.

	Quinsam	Big Qualicum	Chilliwack	Inch	Black	Robertson	Carnation
Observed survival in 2001	0.017	0.021	0.050	0.062	0.073	0.096	0.058
Sibling forecast	0.021	0.027	0.055	0.043		0.039	
% obs of forecast	81%	78%	91%	144%		246%	
Quasi TS model	3YRA	LLY	RAT3	3YRA	3YRA	LLY	3YRA
Forecast	0.011	0.020	0.014	0.012	0.026	0.076	0.031
% obs of forecast	155%	105%	357%	517%	281%	126%	188%
Euphausiid forecast						0.040	0.102
% obs of forecast						240%	57%

The best performing models are shaded, i.e. the models with the least RMSE's and MAD's. Chilliwack, Inch, Black and Robertson stocks survived much better than was forecasted. The forecast for Big Qualicum was accurate, the one for Quinsam was reasonably accurate and the survival at Carnation was much less than predicted. The Carnation forecast used an euphausiid regression model that has now been changed. The observed survivals of Chilliwack, Inch and Black coho exceeded the upper 95% confidence limits of the forecasts. The Big Qualicum, Robertson and Carnation survivals were within the 50% confidence limits of their forecasts.

The utility of sibling models should be reviewed for the next forecast since the sample size from most indicators is sufficient to determine whether they are likely to be of any benefit in the future. To date, they have not out-performed time series models except at Robertson (where time series models suffer from a relative lack of auto-correlation in survivals between years). The review should include an examination of the precision of the data, past and current, because lack of relationships may reflect data problems. Coho jack escapements were not considered useful until recently and hatchery procedures and facilities were not always designed to obtain accurate estimates.

4.2 Forecast Survival in 2002

4.2.1 Euphausiid Model

We found that euphausiid abundance and smolt number do affect Carnation Creek returns and therefore reject the null hypothesis. (Euphausiid biomass was also tested as a measure of feeding conditions; these regressions were also highly significant but the R^2's were lower.) Marine survival rate variation in Carnation Creek coho can be explained by the following regression:

$$ln\,R_{t,x.1} = 0.19 \bullet ln\,E_{t-1} + 0.82 \bullet ln\,S_{t-1} + 1.93 \qquad \text{Eqn. 20}$$

(R^2=0.99, p<0.001, n=9)

All parameter estimates are significantly (p<0.05) different from zero. Standardised regression coefficients (Sokal and Rohlf 1995) showed that smolt and euphausiid abundances account for 74% and 26% of the explained variation respectively. As discussed below, we found a similar relationship for Robertson Creek hatchery coho. However, this relationship broke down in the 2000 return year.

Carnation Creek. We tested Eqn. 20 as a forecaster of Carnation Creek coho returns. Figure 3 shows scatterplots of the natural logarithm of number of returning adults and natural logarithms of number of out-migrating smolts and median euphausiid abundance and biomass. The plots indicated that the data for the 1994 return year did not follow the apparent trends. These data represented fish from the 1991 brood year, which were exposed to high concentrations of mackerel in Barkley Sound as smolts in 1993. We decided that the data for the 1994 return year represented a highly unusual situation and consequently excluded them from the analyses, and from the regression analysis which produced Eqn. 20.

Results of the retrospective analysis of the predictive power of the relationship are presented in Table 7. Retrospective forecasts were made by using the regression for the estimated return in year *t* and the count of out-migrating smolts and euphausiid abundances for the smolt year (*t-1*). We began testing for significant regressions when the data series was five years long. Consequently, analyses began with data up to and including the 1997 return year because we excluded data for 1994. We calculated the 95% CL of the prediction using the equations described in Sokal and Rohlf (1995). Parameter estimates appeared to have stabilised as of the forecasts for the 2000 return year. Returns were under-estimated by one and eight fish in 2000 and 2001 respectively. Results are also presented as marine survival rates so that applicability of the forecast to Kirby Creek can be evaluated (Figure 4). Kirby Creek is another wild coho indicator stream near Sooke but it has a different smolt output. It appears that the survival rate forecasts are accurate and can be used for other wVI wild coho stocks, at least for Kirby Creek.

We used Eqn. 20 to forecast marine survival rate for Carnation Creek coho for 2002. There were 2208 smolts leaving Carnation Creek in 2001 and median *T. spinifera* abundance was very low at 2 individuals • m^{-2}. The forecasted number of returning adults is 89 fish with lower and upper 95% CL of 48 and 164 fish respectively. The forecasted survival rate is 0.04 with lower and upper 95% CL of 0.022 and 0.074 respectively.

<u>Robertson Creek Hatchery</u>. The same analytical procedure was used for Robertson Creek. Scatterplots of the natural logarithm of number of returning adults and natural logarithm of number of out-migrating smolts and median abundance of 9 – 12 mm T. spinifera are shown in Figure 5. As for Carnation Creek, data for the 1994 return year appeared to be an outlier and were excluded because it is likely that mackerel exerted an unusually high predation pressure on coho smolts in 1993. In addition, data for the 2000 and 2001 return years deviate.

Table 8 presents the results of the retrospective analysis of the smolt-euphausiid regression for Robertson Creek Hatchery coho. The parameter estimates were stabilizing over the 1999 and 2000 forecasting years and then appear to be de-stabilizing. Figure 6 shows the forecasts of returning adults as survival rates. Survival rates for the 2000 and 2001 return years were not predicted accurately. Because of the recent poor performance of the forecasts, we will not forecast survival rate for Robertson Creek coho for the 2002 return year. The intent is to continue monitoring the relationship among adult counts, smolt numbers and euphausiid abundance to see if a relationship becomes apparent over time.

4.2.2 Strait of Georgia CPUE Forecast

Hatchery CPUE, non-hatchery CPUE and total CPUE were all significantly correlated with hatchery survival rates Table 9 and Figure 7). Using the strongest relationship, we forecast that the 2002 survival will be 0.034, which is virtually the same as in 2001 (0.035). A regression of unclipped CPUE with Black Creek survivals was not significant (Table 9).

4.2.3 All Models

Survival forecasts and associated confidence intervals are shown for the sibling regressions in Table 10 and for the time-series models in Table 11. The survival forecasts made by the best performing model and associated 50% confidence intervals are summarized in the following table and in Figure 8, Figure 9 and Figure 10:

	Best Models			Alternate Regression Models		
		$\hat{S}_{2002}$	(50% CI)		$\hat{S}_{2002}$	(50% CI)
Big Qualicum	LLY	0.021	(0.014 - 0.032)	Sibling	0.070	(0.042 - 0.117)
Quinsam	3YRA	0.013	(0.010 - 0.018)	Sibling	0.023	(0.016 - 0.034)
Chilliwack	RAT3	0.035	(0.025 - 0.049)	Sibling	0.041	(0.028 - 0.059)
Inch	3YRA	0.026	(0.013 - 0.050)	Sibling	0.023	(0.014 - 0.038)
Black	3YRA	0.030	(0.021 - 0.042)		-	
Robertson:	Sibling	0.031	(0.019 - 0.049)	LLY	0.092	(0.042 - 0.187)
Carnation	Euphausiid	0.040	(0.032 - 0.050)	Sibling	0.161	(0.105 - 0.247)
				3YRA	0.031	(0.016 - 0.057)

The outlook for the Georgia Basin indicators is for poor survivals, similar to or less than 2001. Overall, the CPUE forecast predicts a survival of 0.032, which is similar to the mean of the Georgia Basin survivals forecasted using time series models (0.025). The auto-correlated survivals in the 1990's stopped trending down in 1999 and 2000 so there is increased uncertainty with the trend models at this time. However, the sibling models generally support the time series conclusions, the only large difference being at Big Qualicum, where the sibling model predicts a large increase in survival to 7%.

For Robertson Hatchery, we are faced with conflicting LLY and sibling forecasts of essentially equally poor retrospective performance. A poor jack escapement in 2001 has resulted in a sibling forecast of only 3.1%, a large decrease from the survivals of 10.3% and 9.6% in 2000 and 2001. The LLY model predicts, of course, the same survival as last year, 9.6%. Although the more cautious prediction should normally be favored, the sibling model has badly under-estimated survivals in the last two years (Figure 11). The sibling relation is shown in Figure 12. The forecasts for Carnation Creek coho support a conclusion that Robertson survival and perhaps wVI survivals in general are more likely to decrease than increase. The favored Carnation forecast is the euphausiid model, which predicts 4% survival, a decrease from 5.8% last year. Although not true in the last three years, Carnation coho have usually survived better than Robertson coho (Table 4). The best time series model also predicts a low survival at Carnation. However, the 2001 fence count includes a relatively large number of coho identified as jacks (age data are still unavailable), resulting in a very high forecast of 16%. Neither the time series nor the sibling forecast should be given much weight because they have performed poorly in the past. The sibling relations in wild coho stocks are largely masked by varying jacking rates, partly due to annual variation in smolt size (e.g. Holtby and Kadowaki 1996) and perhaps timing. On balance, we have opted for a forecast of 3.1% but are more confident in simply predicting survivals will decrease.

5. Forecast of Distribution

The forecast of catch proportion inside is:

$$\log it(\hat{p}_{inside}) = 1.002GSsal - 28.9 \qquad \text{Eqn. 21}$$

(N=23; adj. $r^2 = 0.69$; P << 0.001)

where GSsal is the mean of the mean February salinities at Sisters and Chrome islands. This fit is to the pre-1998 data only, when catch data were still available. The average salinity at Sisters and Chrome islands in February was 28.19‰. Figure 13 shows the fitted relationship and a probability plot of the confidence interval for p_{inside}. Confidence levels are tabulated in Table 12. The predicted value of 0.35 is indicative of a return to an 'outside distribution' of moderate strength. The confidence intervals indicate that there is a probability of less than 1% that 2002 will be an 'inside year' as strong as the 0.70 estimated in 2001. So far there have been reports of 'bluebacks' (age x.1 coho starting their last year) in the Victoria area (pers. comm., S. Moore, Pedder Bay Marina, Victoria) but we are not aware of abundances further into the Strait. A proportion of 0.35 is comparable to the proportion observed in 1994 and forecast for 1999 and 2000. It is not as low as was observed in 1991 and from 1995 to 1998 (Simpson et al. 2001b).

6. Forecast of Abundance – Interior Fraser Coho

Although coho returning to the interior Fraser are part of the Strait of Georgia-Fraser stock aggregate, they are considered separately because of the role they continue to play in determining salmon fisheries management in southern B.C.

In retrospective analysis, the averaging models (LLY and 3YRA) once again outperformed the ratio models in forecasting total returns to the Thompson system (Table 13). The 3YRA model continues to be the model of choice for the Thompson watershed. The time series of abundance estimates for coho in the Thompson River watershed is shown in Figure 14. The time series of reliable escapement data for non-Thompson systems in the interior Fraser is too short to evaluate model performance.

Forecasts of total abundance for 2001 provided in last year's forecast document (Simpson et al. 2001a) were evaluated by comparing these forecasts with estimated coho abundance (Table 14). The 3YRA model underestimated abundance to all sections of the Thompson system, and to the watershed as a whole. Forecasts were 40%, 32%, 33% and 35% of observed abundances for the Lower Thompson, South Thompson, North Thompson and total Thompson watershed, respectively.

The abundance of Thompson watershed coho in 2001 was ~54,000 (Table 3), which exceeded the brood year (1998) abundance of ~18,000. Thompson escapements in 2001 (~49,500) were much greater than 1998 escapements (~16,700). These increases may be attributed to increased marine survival and reductions in the fishery.

We forecast that the abundance of Thompson River coho in 2002 will be less than observed abundances in 2001 (Table 15; Figure 14). Based on the 3YRA model, we predict ~25,000 coho will survive to adulthood and be available to return to the watershed. The forecast return to the Thompson River watershed is approximately 29% of the mean abundance of the time series. We are unable to forecast returns to the non-Thompson streams due to the extremely short time series of reliable escapement data (n=4).

7. Conclusions

7.1 Marine survival

Recommendations for the marine survival forecast for the five hatchery indicators and two wild coho indicators are given in the following table:

Indicator	Recommended Model	Predicted Survival in 2002 (50% CI)	Change (2002 forecast minus 2001 observed S)
Big Qualicum	LLY	0.021 (0.014 - 0.032)	0
Quinsam	3YRA	0.013 (0.010 - 0.018)	-0.004
Chilliwack	RAT3	0.035 (0.025 - 0.049)	-0.015
Inch	3YRA	0.026 (0.013 - 0.050)	-0.036
Black	3YRA	0.030 (0.021 - 0.042)	-0.043
Robertson:	Sibling	0.031 (0.019 - 0.049)	-0.065
Carnation	Euphausiid	0.040 (0.032 - 0.050)	-0.018

Predictions by PSC Management Unit follow:

7.1.1 Georgia Basin West (GBW, Vancouver Island coast of the Strait of Georgia). Survival of coho on the east coast of Vancouver Island is forecast to be poor, in the 1.3% to 3% range. Black Creek and perhaps other wild stocks showed a substantially improved survival in 2001. However, the prediction is that marine survival of the 1999 brood at Black Creek will drop to 3% this year from 7.3% last year. The sibling forecasts for Quinsam and Big Qualicum have not performed as well as time series models in the past but do have R^2 values of >0.7. Those forecasts are for a large increase at Big Qualicum from 2.1% to 7% and a small increase at Quinsam, from 1.7% to 2.3%. Although the Big Qualicum sibling forecast is contrary to the conclusion that survivals will be poor in this unit, the Quinsam sibling forecast confirms the favored time series forecast, which is also for a poor survival.

7.1.2 Georgia Basin East (GBE, Mainland coast of the Strait of Georgia). Not having the first return of coded wire tagged coho back to our new indicator stream in Powell River (Myrtle Creek) and not having other indicators in this area, we cannot make a prediction. Fry, smolt and escapement data (Simpson et al. 2001b) suggest that marine survivals have been at least as poor as seen in GBW.

7.1.3 Lower Fraser (LWFR, Howe Sd. and Lower Mainland to Hells Gate). The forecast survivals of Inch and Chilliwack hatchery coho of 2.6% and 3.5% indicate survival of Lower Fraser coho will be poor (although higher than in the GBW unit). The sibling relationship is fair for Chilliwack coho (R^2 = 0.72) but not for Inch (R^2=0.38). The Chilliwack sibling forecast is similar to the favored time series forecast: 4.1% vs. 3.5%, respectively, both down from the 2001 survival of 5.0%. The Inch time series forecast is also for lower survival in 2002. The Salmon River time series of survivals is correlated with Inch and Chilliwack survivals (Simpson et al 2001b). Based on that, survivals of wild coho in this unit are expected to also decrease although they should survive better than hatchery coho.

7.1.4 Georgia Basin Summary (GBE, GBW and LWFR). We present a forecast for the mean of the four Georgia Basin hatchery indicators of 3.2% based on the catch obtained in the 2001 trawl surveys in the Strait of Georgia. The mean survival last year was 3.5% so this predicts little change. This survival and the time series forecasts can be characterized as poor, relative to survivals experienced 10 to 20 years ago and in terms of the low exploitations that are necessary at these survivals for Georgia Basin populations to sustain themselves.

7.1.5 Southwest Vancouver Island (SWVI, Victoria to Estevan Pt.). Forecasts of survival of Robertson Hatchery and Carnation Creek coho are for 3.1% and 4%, respectively. Both represent decreases from survivals seen in the previous brood, substantially so for Robertson. Forecasts of survival have always been problematic in this region and the Robertson forecast is particularly tenuous this year. It is more realistic to simply predict that survivals of the 1999 brood will be lower than seen last year for the 1998 brood.

7.1.6 Northwest Vancouver Island (NWVI, Estevan Pt. to Cape Scott). We do not have indicator forecasts for this area. However, fry and escapement data and returns to Conuma Hatchery (north of Gold River) suggest that marine survivals are similar to SWVI survivals.

7.2 Abundance of Interior Fraser Coho

7.2.1 The forecast total abundance of Thompson River watershed coho in 2002 is ~25,000, which is about half the observed abundance in 2001. It does represent a forecasted increase over the 1999 brood abundance of 18,700, however. The escapement in 2001 was the largest since 1989 and escapements in 2000 and 1999 were larger than brood year escapements. Greater proportions of fish that are surviving to maturity are returning to spawn because of the significant reductions in fishing pressure. Thus, assuming marine survivals and fishing pressures remain low, the outlook for Thompson and other interior Fraser coho is for slow improvement.

7.3 Distribution

7.3.1 In the hypothetical circumstance of historical patterns of fishing, the predicted proportion of catch inside the Strait of Georgia (p_{inside}) would be 0.35 (50% CI: 0.27–0.45), which can be characterized as a moderate outside distribution. A strong inside year is very unlikely. This means that Georgia Basin stocks will be more susceptible to potential wVI and Strait of Juan de Fuca fisheries.

8. References

Beamish, R.J. and M. Folkes. 1998. Recent changes in the marine distribution of juvenile chum salmon off Canada. INPAFC Bull. 1: 443-453.

Beamish, R.J., D McCaughran, J.R. King, R.M. Sweeting and G.A. MacFarlane. 2000a. Estimating the abundance of juvenile coho salmon in the Strait of Georgia by means of surface trawls. N. Am. J. Fish. Manag. 20: 369-375.

Beamish, R.J., D.J. Noakes, G.A. MacFarlane, W. Pinnix, R. Sweeting and J. King. 2000b. Trends in coho marine survival in relation to the regime concept. Fish. Oceanog. 9:114-119.

Dobson, D., K. Simpson, J. Till, S. Lehmann, R. Ferguson, P. Tschaplinski, and S. Baillie. 2000. Status in 1999 of coho stocks on the west coast of Vancouver Island. Fisheries and Oceans Canada (Ottawa), Can. Stock Assess. Secret. Res. Doc. 2000/160: 60p.

Holtby, L.B., and R. Kadowaki. 1996. Forecast of 1997 return of coho to west Vancouver Island with comments on the implications of the poor brood year (1994) escapement. PSARC Working Paper S96-22: 23p.

Holtby, L.B., J. Irvine, R. Tanasichuk, and K. Simpson. 1999. Forecast for southern British Columbia coho salmon in 1999. Fisheries and Oceans Canada (Ottawa), Can. Stock Assess. Secret. Res. Doc. 99/125.

Holtby, L.B., K. Simpson, R. Tanasichuk, and J.R. Irvine. 2000. Forecast for southern British Columbia coho salmon in 2000. Fisheries and Oceans Canada (Ottawa), Can. Stock Assess. Secret. Res. Doc. 2000/127: 43p.

Irvine, J. R., K. Wilson, B. Rosenberger, and R. Cook. 1999a. Stock assessment of Thompson River/Upper Fraser River coho salmon. Fisheries and Oceans Canada (Ottawa), Can. Stock Assess. Secret. Res. Doc. 99/28.

Irvine, J. R., R. E. Bailey, M. J. Bradford, R. K. Kadowaki, and W. S. Shaw. 1999b. 1999 assessment of Thompson River/Upper Fraser River coho salmon. Fisheries and Oceans Canada (Ottawa), Can. Stock Assess. Secret. Res. Doc. 99/128.

Irvine, J. R., R. E. Withler, M. J. Bradford, R. E. Bailey, S. Lehmann, K. Wilson, J. Candy, and W. Shaw. 2000. Stock status and genetics of interior Fraser coho salmon. Fisheries and Oceans Canada (Ottawa), Can. Stock Assess. Secret. Res. Doc. 2000/125.

Kadowaki, R. 1997. 1997 forecasts of marine survival and catch distribution for Strait of Georgia coho salmon. PSARC Working Paper 97-6.

Kadowaki, R., L. 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 S96-9: 43p.

Kadowaki, R., and L.B. Holtby. 1998. 1998 forecasts of marine survival rate, marine distribution and pre-fishery abundance for southern B.C. coho salmon. PSARC Working Paper S98-5.

Pacific Salmon Commission. 2002. Investigations of methods to estimate mortalities of unmarked salmon in mark-selective fisheries through the use of double index tag groups. Report of the Selective Fishery Evaluation Committee. TCSFEC(02)-1: 101p.

Petersen, W.T., R.D. Brodeur, and W.G. Pearcy. 1982. Food habits of juvenile salmon in the Oregon coastal zone. Fish. Bull. (U.S.) 80: 841-851.

Schnute, J. T., T.J. Mulligan, and B. R. Kuhn. 1990. An errors-in-variables model with an application to salmon hatchery data. Can. J. Fish. Aquat. Sci. 47: 1453-1467.

Simpson, K., R. Semple, D. Dobson, J.R. Irvine, S. Lehmann, and S. Baillie. 2000. Status in 1999 of coho stocks adjacent to the Strait of Georgia. Fisheries and Oceans Canada (Ottawa), Can. Stock Assess. Secret. Res. Doc. 2000/158: 90p.

Simpson, K., D. Dobson, J.R. Irvine, L.B. Holtby, and R.W. Tanasichuk. 2001a. Forecast for southern British Columbia coho salmon in 2002. Fisheries and Oceans Canada (Ottawa), Can. Stock Assess. Secret. Res. Doc. 2001/107: 50p.

Simpson, K., D. Dobson, R. Semple, S. Lehmann, S. Baillie, and I. Matthews. 2001b. Status in 2000 of coho stocks adjacent to the Strait of Georgia. Fisheries and Oceans Canada (Ottawa), Can. Stock Assess. Secret. Res. Doc. 2001/144: 95p.

Sokal, R. R. and F. J. Rohlf. 1995. Biometry: The Principles and Practice of Statistics in Biological Research. W. H. Freeman, New York. 887p.

Tanasichuk, R. W. 1998. Interannual variations in the population biology and productivity of *Euphausia pacifica* in Barkley Sound, Canada, with special reference to the 1992 and 1993 warm ocean years. Mar. Ecol. Prog. Ser. 173: 163-180.

TABLES

Table 1. Estimates of fishing mortality in 2001 on indicator stocks. Estimates do not include test fisheries, aboriginal fisheries or freshwater sport fisheries.

Gear/Area	INCH	CHILLIWACK	BLACK	RCH	QUINSAM	BIGQ	THOMPSON
Gillnet	0.3%	0.0%	0.1%	0.1%	0.1%	1.0%	0.0%
Seine	0.2%	0.0%	0.3%	0.0%	0.2%	0.8%	0.1%
Troll	0.4%	0.2%	0.5%	0.4%	0.3%	0.2%	0.4%
Marine Sport	6.2%	4.7%	1.1%	22.7%	5.4%	5.6%	0.7%
Southern US	2.6%	2.2%	0.6%	0.4%	0.6%	1.0%	5.6%
Alaska	0.0%	0.1%	1.6%	1.0%	0.1%	0.1%	0.3%
Mortality Estimate	9.6%	7.2%	4.3%	24.4%	6.7%	8.7%	7.1%
Canadian Mortality	7.0%	4.9%	1.8%	23.2%	5.8%	7.5%	1.2%

* Note these estimates do not include freshwater sport fisheries or test fisheries.

Table 2. Streams in the interior Fraser data sets. The ‘W’ and ‘E’ indicate wild and enhanced streams respectively although it is realized that many of the wild steams are to a certain degree, enhanced.

Non-Thompson/Fraser		Lower Thompson		South Thompson		North Thompson	
Beaver Creek	W	Bonaparte River	W	Adams River (lwr)	W	Albreda River	W
River Bridge	W	Nicola River (lower)	W	Adams River (up)	W	Avola Creek	W
Chilko River	W	Nicola River (upper)	W	Anstey River	W	Barrierre River	W
McKinley Creek	W	Tranquille Creek	W	Bessette Creek	W	Blue River	W
Mitchell River	W	Coldwater River	E	Blurton Creek	W	Brookfield. Creek	W
Nahatlatch River	W	Deadman River	E	Bolean Creek	W	Cedar Creek	W
Portage Creek	W	Spius Creek	E	Canoe Creek	W	Clearwater. River	W
Cayoosh Creek	W			Cayenne Creek	W	Cook Creek	W
Seton River	W			Creighton Creek	W	Crossing Creek	W
Summit Creek	W			Danforth Creek	W	E. Barrierre River	W
				Duteau Creek	W	Fennel Creek	W
				Harris Creek	W	Finn Creek	W
				Huihill Creek	W	Goose Creek	W
				Hunakwa Creek	W	Haggard Creek	W
				Ireland Creek	W	Lion Creek	W
				Johnson Creek	W	Mahood River	W
				Kingfisher Creek	W	Mann Creek	W
				McNomee Creek	W	McTaggart Creek	W
				Momich Creek	W	N. Thompson River	W
				Noisey Creek	W	Raft River	W
				Onyx Creek	W	Reg Christie Creek	W
				Owlhead Creek	W	Shannon Creek	W
				Scotch Creek	W	Tumtum Creek	W
				Seymour River	W	Wireca. Creek	W
				Shuswap River (lwr)	W	Dunn Creek	E
				Shuswap River (mid)	W	Lemieux Creek	E
				Sinmax Creek	W	Louis Creek	E
				South Pass Creek	W		
				Tappen Creek	W		
				Trinity Creek	W		
				Wap Creek	W		
				Eagle River	E		
				Salmon River	E		

Table 3. Estimated fishery exploitation rates (expl), escapements (esc), marine fishery catches, and total abundances (abund) for interior Fraser coho salmon.

Return		South Thompson			North Thompson			Lower Thompson			Non-Thompson Fraser		
Year	expl	esc	catch	abund	esc	catch	abund	esc	catch	abun	esc	catch	abund
1975	0.68	5864	12490	18354	22286	47468	69754						
1976	0.68	3920	8349	12268	20675	44037	64713						
1977	0.68	8490	18082	26572	42804	91171	133975						
1978	0.68	7996	17032	25028	39095	83269	122364						
1979	0.68	10198	21720	31918	47819	101851	149670						
1980	0.68	7025	14964	21989	10542	22454	32996						
1981	0.68	4120	8775	12895	20615	43909	64524						
1982	0.68	5849	12459	18308	42295	90087	132382						
1983	0.68	6196	13196	19392	35086	74731	109816						
1984	0.68	15394	32789	48183	69552	148141	217692	5155	12050	17205			
1985	0.68	16998	36205	53204	45160	96188	141349	1913	4060	5973			
1986	0.66	16521	31665	48186	104267	199846	304113	2211	4300	6511			
1987	0.54	21087	24478	45564	54884	63710	118594	4208	4945	9153			
1988	0.71	24426	60376	84802	70612	174539	245150	4013	9830	13843			
1989	0.65	17208	31288	48496	30677	55779	86455	3423	6340	9763			
1990	0.74	8609	24069	32677	25697	71844	97542	4421	12600	17021			
1991	0.68	4160	8737	12896	14585	30633	45217	3794	8825	12619			
1992	0.81	11886	52239	64125	22042	96875	118917	4905	21000	25905			
1993	0.88	1873	13172	15045	9669	67999	77667	8416	61500	69916			
1994	0.43	4485	3430	7915	10031	7671	17702	5252	3965	9217			
1995	0.56	3622	4639	8261	22477	28794	51272	1984	2525	4509			
1996	0.83	1760	8906	10667	12319	62325	74645	1209	5900	7109			
1997	0.40	2034	1384	3418	6722	4573	11295	4217	2820	7037			
1998	0.07	4946	375	5321	9125	685	9810	2628	200	2828	8147	610	8757
1999	0.09	3074	305	3379	8916	885	9801	5007	495	5502	5389	535	5924
2000	0.034	3785	134	3919	7032	250	7282	4459	157	4616	4723	144	4867
2001	0.080	13239	1157	14396	26433	2311	28744	9828	859	10687	13515	1182	14697

Table 4. Release and recovery summaries for the seven indicator streams used to generate forecasts.

Brood Year	CWT smolt release[1]	Estimated Return		Marine Survival
		Age x.0 (jacks)	Age x.1	Age x.1
Quinsam R. Hatchery				
1975	97,560	2,205	7,130	0.073
1976	159,136	3,243	9,302	0.058
1977	168,286	2,178	16,784	0.100
1978	226,186	2,308	12,614	0.056
1979	280,127	3,118	13,393	0.048
1980	57,385	410	4,033	0.070
1981	102,021	660	5,541	0.054
1982	147,404	1,132	11,182	0.076
1983	57,764	514	6,567	0.114
1984	57,573	726	4,515	0.078
1985	42,176	925	3,352	0.079
1986	44,457	847	4,731	0.106
1987	39,362	792	3,067	0.078
1988	39,466	298	1,649	0.042
1989	39,400	250	2,312	0.059
1990	39,411	233	1,367	0.035
1991	42,470	315	964	0.023
1992	36,277	276	910	0.025
1993	38,947	128	535	0.014
1994	80,125	247	934	0.012
1995	82,351	644	772	0.009
1996	39,813	90	339	0.009
1997	39,322	202	646	0.016
1998	42,354	188	710	0.017
1999	42,999	212		
Big Qualicum Hatchery				
1972	113,018	1,398	40,122	0.355
1973	57,425	928	16,584	0.289
1974	75,512	1,481	12,366	0.164
1975	210,520	5,858	28,029	0.133
1976	150,348	1,511	28,427	0.189
1977	101,224	620	21,439	0.212
1978	107,328	543	12,176	0.113
1979	55,435	732	5,706	0.103
1980	51,984	271	5,792	0.111
1981	49,274	643	3,882	0.079
1982	42,453	181	2,129	0.050
1983	21,868	33	188	0.009
1984	87,365	71	544	0.006
1985	74,194	440	1,112	0.015
1986	27,462	95	356	0.013
1987	42,412	388	1,814	0.043
1988	44,813	246	2,758	0.062
1989	36,474	186	2,135	0.059
1990	37,362	363	2,497	0.067
1991	38,235	188	2,617	0.068
1992	37,957	48	1,122	0.030
1993	38,917	237	621	0.016
1994	37,616	87	535	0.014

Table 4. (continued)

Brood Year	CWT smolt release[1]	Estimated Return		Marine Survival
		Age x.0 (jacks)	Age x.1	Age x.1
Big Qualicum Hatchery (continued)				
1995	38,827	41	223	0.006
1996	40,331	144	441	0.011
1997	37,806	64	712	0.019
1998	40,836	135	860	0.021
1999	40,596	316		
Chilliwack R. Hatchery				
1980	54,665	585	6,543	0.120
1981	28,502	408	4,090	0.143
1982	100,841	757	18,865	0.187
1983	27,851	153	3,664	0.132
1984	129,770	554	22,536	0.174
1985	59,935	844	10,847	0.181
1986	68,658	350	8,698	0.127
1987	39,250	269	4,166	0.106
1988	39,801	233	3,605	0.091
1989	39,500	151	2,245	0.057
1990	39,797	152	2,360	0.059
1991	39,673	87	2,536	0.064
1992	39,654	153	1,480	0.037
1993	39,808	206	1,584	0.040
1994	36,256	75	899	0.025
1995	74,456	130	1,001	0.013
1996	37,282	43	541	0.015
1997	82,059	42	1,921	0.023
1998	36,976	112	1,863	0.050
1999	42,795	106		
Inch Cr. Hatchery				
1983	38,711	26	2,562	0.066
1984	38,774	197	3,442	0.089
1985	19,723	149	4,007	0.203
1986	19,504	21	2,121	0.109
1987	27,458	126	2,203	0.080
1988	38,019	36	2,690	0.071
1989	29,367	37	2,850	0.097
1990	31,629	101	2,608	0.082
1991	21,172	111	1,282	0.061
1992	20,303	10	1,115	0.055
1993	21,540	90	835	0.039
1994	21,174	5	225	0.011
1995	38,707	12	243	0.006
1996	41,918	7	832	0.020
1997	60,313	73	834	0.014
1998	40,201	63	2,488	0.062
1999	39,911	16		

Table 4. (continued)

Brood Year	CWT smolt release[1]	Estimated Return		Marine Survival
		Age x.0 (jacks)	Age x.1	Age x.1
Black Creek (Wild Indicator)				
1983	24,134	95	3,016	0.125
1984	31,648	46	3,617	0.114
1985	35,640	455	4,510	0.127
1986	74,997	305	8,529	0.114
1987	29,203	559	3,628	0.124
1988	118,382	824	9,028	0.076
1989	52,351	1,837	6,399	0.122
1990	49,873	1,710	3,156	0.063
1991	54,898	757	3,162	0.058
1992	76,003	1,214	3,459	0.046
1993	18,152	1,079	609	0.034
1994	13,736	280	597	0.043
1995	69,996	242	3,213	0.046
1996	24,582	523	407	0.017
1997	26,247	575	577	0.022
1998	151,129	1,950	10,990	0.073
1999	42,420	2,700		
Robertson Cr. Hatchery				
1973	44,071	1,231	3,415	0.077
1974	55,672	1,055	4,011	0.072
1975	51,460	1,628	2,515	0.049
1976	43,047	486	3,773	0.088
1977	51,019	433	2,373	0.047
1978	51,916	307	1,168	0.022
1979	48,776	110	975	0.020
1980	144,742	1,037	8,193	0.057
1981	125,895	1,055	8,657	0.069
1982	94,740	44	1,932	0.020
1983	52,092	85	2,038	0.039
1984	46,061	54	1,335	0.029
1985	41,474	85	765	0.018
1986	50,967	412	2,514	0.049
1987	61,191	616	5,525	0.090
1988	43,524	140	2,567	0.059
1989	41,773	57	1,926	0.046
1990	40,221	140	963	0.024
1991	38,419	1	18	0.000
1992	36,873	2	464	0.013
1993	42,248	23	755	0.018
1994	43,005	228	1,310	0.030
1995	39,566	54	1,389	0.035
1996	39,578	57	834	0.021
1997	40,499	67	4,161	0.103
1998	40,207	92	3,843	0.096
1999	40,068	73		

Table 4. (continued)

Brood Year	CWT smolt release[1]	Estimated Return		Marine Survival
		Age x.0 (jacks)	Age x.1	Age x.1
Carnation Creek (wild indicator)[2]				
1972	2,658	75	327	0.123
1973	2,121	54	260	0.123
1974	3,062	35	268	0.088
1975	2,560	53	172	0.067
1976	4,646	233	708	0.152
1977	3,530	114	324	0.092
1978	4,567	101	235	0.052
1979	4,164	61	525	0.126
1980	3,470	61	321	0.092
1981	3,745	83	200	0.053
1982	3,113	25	188	0.060
1983	1,978	59	323	0.163
1984	2,833	27	143	0.050
1985	2,648	58	204	0.077
1986	2,712	98	514	0.190
1987	3,862	160	599	0.155
1988	3,222	128	609	0.189
1989	3,103	51	385	0.124
1990	5,253	43	388	0.074
1991	3,989	6	24	0.006
1992	4,759	104	432	0.091
1993	3,480	90	165	0.047
1994	892	85	76	0.085
1995	4,942	123	293	0.059
1996	4,865	69	49	0.010
1997	2,842	79	136	0.048
1998	4,828	86	281	0.058
1999	2,205	115		

[1] After 1995, marine survival is calculated only from CWT-ad groups. Carnation and Black smolt abundances include some age 2. smolts from the previous brood year.

[2] Up to the 1999 brood year, the catch component of Carnation returns and survivals was estimated by assuming exploitations equal to Robertson Hatchery. For 1999, an exploitation of 5% was assumed for now (see text).

Table 5. Catches of age x.0 coho in the Strait of Georgia during July trawl surveys.

Brood Year	Catch Year	No. of Sets	Catch Ad Clip	Catch Not Clipped	Catch Total
1995	1997	69	158	307	465
1996	1998	95	474	789	1,263
1997	1999	98	660	989	1,649
1998	2000	85	2,144	406	2,550
1999	2001	107	2,572	577	3,149

Table 6 Performance of survival forecasts for 2001, showing the model, the observed survival and the forecast with confidence limits.

	Strait of Georgia indicators					wVI Indicators	
	Quinsam	Big Qualicum River	Chilliwack	Inch	Black (wild)	Robertson	Carnation (wild)
Survival 2001 (observed)	**0.017**	**0.021**	**0.050**	**0.062**	**0.073**	**0.096**	**0.058**
Model	3YRA	LLY	RAT3	3YRA	3YRA	Sibling	Euphausiid
CI:75%[1]	0.014	0.031	0.019	0.023	0.033	0.058	0.179
Forecast	**0.011**	**0.020**	**0.014**	**0.012**	**0.026**	**0.039**	**0.102**
CI:25%	0.008	0.012	0.011	0.006	0.021	0.026	0.044
CI:10%	0.006	0.008	0.008	0.003	0.016	0.018	0.024
CI:5%	0.006	0.006	0.007	0.002	0.014	0.014	0.013
CI:1%	0.004	0.004	0.005	0.001	0.010	0.009	0.000

[1] In this case 75% of the observed values are expected to be less than the stated value.

Table 7 Retrospective analysis of Carnation Creek coho survival rate forecasts made using the smolt-euphausiid multiple regression.

				Regression Coefficients					Returning Adults	
Forecast Year	n	Ln smolts	Ln *T.spinifera*	Intercept	Smolt	*T. spinifera*	R^2	p	Predicted	Observed
1998	5	8.50	3.33	-8.64	1.58	0.49	0.99	0.005	615	292
1999	6	8.49	2.52	-2.99	1.01	0.11	0.98	0.001	351	49
2000	7	7.96	1.79	-1.87	0.81	0.18	0.98	0.001	134	135
2001	8	8.48	2.94	-1.85	0.81	0.18	0.98	0.001	257	265

Table 8 Retrospective analysis of Robertson Creek coho survival rate forecasts made using the smolt-euphausiid multiple regression.

				Regression Coefficients					Returning Adults	
Forecast Year	n	Ln smolts	Ln *T.spinifera*	Intercept	Smolt	*T. spinifera*	R^2	p	Predicted	Observed
1998	5	10.59	3.33	-47.67	5.10	0.14	0.99	0.005	902	1,394
1999	6	10.59	2.52	-31.73	3.58	0.22	0.98	0.001	843	837
2000	7	10.61	1.79	-31.76	3.58	0.22	0.98	0.001	748	3,103
2001	8	10.60	2.94	-67.57	7.07	-0.12	0.98	0.001	1,118	3,641

Table 9. Catch per unit effort of age x.0 coho in the Strait of Georgia during July trawl surveys and the mean marine survival of coho from Chilliwack, Inch, Big Qualicum and Quinsam hatcheries. Also shown are Black Cr. coho survivals and statistics for regressions of survival on CPUE.

Brood Year	Catch Year	CPUE Hatchery	CPUE 'Wild'[1]	CPUE Total	Mean Hatchery Survival (%)	Black Cr. Survival (%)
1995	1997	7.42	4.71	12.13	0.8	4.3
1996	1998	14.09	12.71	26.80	1.4	1.7
1997	1999	20.52	13.30	33.82	1.9	2.2
1998	2000	68.40	40.45	108.85	3.5	7.1
1999	2001	59.96	41.69	101.65		
Regression 1:	Mean Hatchery Survival (%) = a + b*CPUE					
	a	-	-	0.676		
	b	-	-	0.026		
	adj R^2	0.948	0.951	0.954		
	Probability	0.0174	0.0165	0.0155		
	Forecast	-	-	**3.4%**	**(50% CI: 2.9 - 3.8)**	
Regression 2:	Black Survival (%) = a + b*CPUE					
	a	-	1.728	-		
	b	-	0.118	-		
	adj R^2	-	0.338	-		
	Probability	-	0.253	-		
	Forecast	-	(not significant)	-		

[1] This catch actually includes some unclipped enhanced coho other than unclipped smolt releases from Str. of Georgia hatcheries (unmarked US hatchery coho; fry releases etc.). Canadian unclipped smolt releases have been deducted from this unmarked group (see text).

Table 10 Forecasts, using sibling regressions, of adult returns and survivals in 2002 for the four Strait of Georgia hatchery indicators and two wVI indicators.

	Big Qualicum	Chilliwack	Quinsam	Inch	Robertson	Carnation
a (intercept)	1.568	2.933	1.456	5.465	4.935	2.539
b (slope)	1.109	0.971	1.018	0.489	0.507	0.703
N	27	19	24	16	27	27
r^2 adjusted	0.78	0.72	0.79	0.38	0.68	0.38
Tagged Smolt Release (2001)[1]	40,596	42,795	42,999	39,911	40,068	2,205
Jack Return (2001)	316	106	212	16	73	115
Predicted Adult Return (2002)	2,839	1,739	1,001	917	1,224	356
Predicted Survival (2002)	**0.070**	**0.041**	**0.023**	**0.023**	**0.031**	**0.161**
Confidence Intervals:						
1%	0.011	0.010	0.006	0.003	0.006	0.034
5%	0.020	0.016	0.009	0.006	0.010	0.056
10%	0.026	0.020	0.011	0.009	0.013	0.071
25%	0.042	0.028	0.016	0.014	0.019	0.105
75%	0.117	0.059	0.034	0.038	0.049	0.247

[1] Ad-CWT releases except for Carnation smolts, which were CWT-only.

Table 11 Time series forecasts of survival of adult coho returning to southern BC indicators in 2002.

	Strait of Georgia indicators					wVI Indicators	
	Quinsam	Big Qualicum	Chilliwack	Inch	Black (wild)	Robertson	Carnation (wild)
Model	3YRA	LLY	RAT3	3YRA	3YRA	LLY	3YRA
CI:75%[1]	0.018	0.032	0.049	0.050	0.042	0.187	0.057
2002 forecast	**0.013**	**0.021**	**0.035**	**0.026**	**0.030**	**0.092**	**0.031**
CI:25%	0.010	0.014	0.025	0.013	0.021	0.042	0.016
CI:10%	0.008	0.009	0.018	0.007	0.015	0.020	0.009
CI:5%	0.007	0.007	0.015	0.004	0.012	0.013	0.006
CI:1%	0.005	0.004	0.010	0.002	0.008	0.005	0.003

[1] In this case, 75% of observed values are expected to be less than the stated value.

Table 12 Forecast of p_{inside} in 2002 for Strait of Georgia hatchery indicators, where p_{inside} is an index of the proportion of coho residing in the Strait in their second year of ocean life.

Parameter	p_{inside}
a	-28.9
b	1.002
N	23
Confidence Intervals:	
1% lower	0.111
5% lower	0.166
10% lower	0.201
25% lower	0.267
Forecast	**0.353**
75% lower	0.450
90% lower	0.542
95% lower	0.599
99% lower	0.705

Table 13 Retrospective analysis of performance of four models in predicting the abundance of coho salmon in the interior Fraser. The recommended model is shaded.

		LLY	3YRA	RAT1	RAT3
South Thompson	*RMSE*	19757	18049	87311	25907
	MAD	13048	13450	35682	18628
	n	26	24	25	23
North Thompson	*RMSE*	79601	65750	191318	114598
	MAD	59757	51348	132429	80855
	n	26	24	25	23
Lower Thompson	*RMSE*	18994	16118	50437	31244
	MAD	10238	9180	19343	15108
	n	17	15	16	14
Total Thompson	*RMSE*	104751	75145	251413	113838
	MAD	80051	62618	170681	82313
	n	17	15	16	14
Fraser/non-Thompson	*RMSE*	5938	NA	7573	NA
	MAD	4573	NA	5736	NA
	n	3	1	2	0
Total Interior Fraser	*RMSE*	27729	NA	36129	NA
	MAD	17945	NA	26516	NA
	n	3	1	2	0

Table 14 Performance of 2001 forecasts of total abundance for the Thompson River watershed. All forecasts were based on the 3YRA model.

	Lower Thompson		South Thompson		North Thompson		Total Thompson	
CI	Forecast	Observed	Forecast	Observed	Forecast	Observed	Forecast	Observed
99%	3.3E+04		2.2E+04		6.0E+04		8.2E+04	
95%	1.7E+04		1.3E+04		3.3E+04		5.0E+04	
90%	1.2E+04		1.0E+04		2.5E+04		4.0E+04	
75%	7.4E+03		6.6E+03		1.5E+04		2.7E+04	
50%	**4.3E+03**	**1.1E+04**	**4.2E+03**	**1.4E+04**	**9.1E+03**	**2.9E+04**	**1.8E+04**	**5.4E+04**
25%	2.4E+03		2.7E+03		5.5E+03		1.2E+04	
10%	1.5E+03		1.8E+03		3.4E+03		8.1E+03	
5%	1.1E+03		1.4E+03		2.5E+03		6.3E+03	
1%	5.6E+02		8.2E+02		1.4E+03		3.9E+03	

Table 15 Forecasts of total abundance for Thompson River watershed coho in 2002 and associated confidence intervals. All forecasts were based on the 3YRA model. The number of years in each time series is given (n).

	Lower Thompson		South Thompson		North Thompson		Total Thompson	
CI	Return	% of Mean	Return	% of Mean	Return	% of Mean	Return	% of Mean
	n=15		n=24		n=24		n=15	
99%	5.5E+04	570%	3.2E+04	177%	8.9E+04	140%	1.6E+05	181%
95%	2.7E+04	282%	1.9E+04	103%	4.8E+04	76%	8.6E+04	99%
90%	1.9E+04	201%	1.4E+04	79%	3.6E+04	56%	6.4E+04	74%
75%	1.1E+04	118%	9.2E+03	51%	2.2E+04	34%	4.1E+04	47%
50%	**6.5E+03**	**67%**	**5.8E+03**	**32%**	**1.3E+04**	**20%**	**2.5E+04**	**29%**
25%	3.7E+03	38%	3.6E+03	20%	7.4E+03	12%	1.6E+04	18%
10%	2.2E+03	22%	2.3E+03	13%	4.5E+03	7%	9.8E+03	11%
5%	1.5E+03	16%	1.8E+03	10%	3.3E+03	5%	7.4E+03	8%
1%	7.6E+02	8%	1.0E+03	6%	1.8E+03	3%	4.0E+03	5%

FIGURES

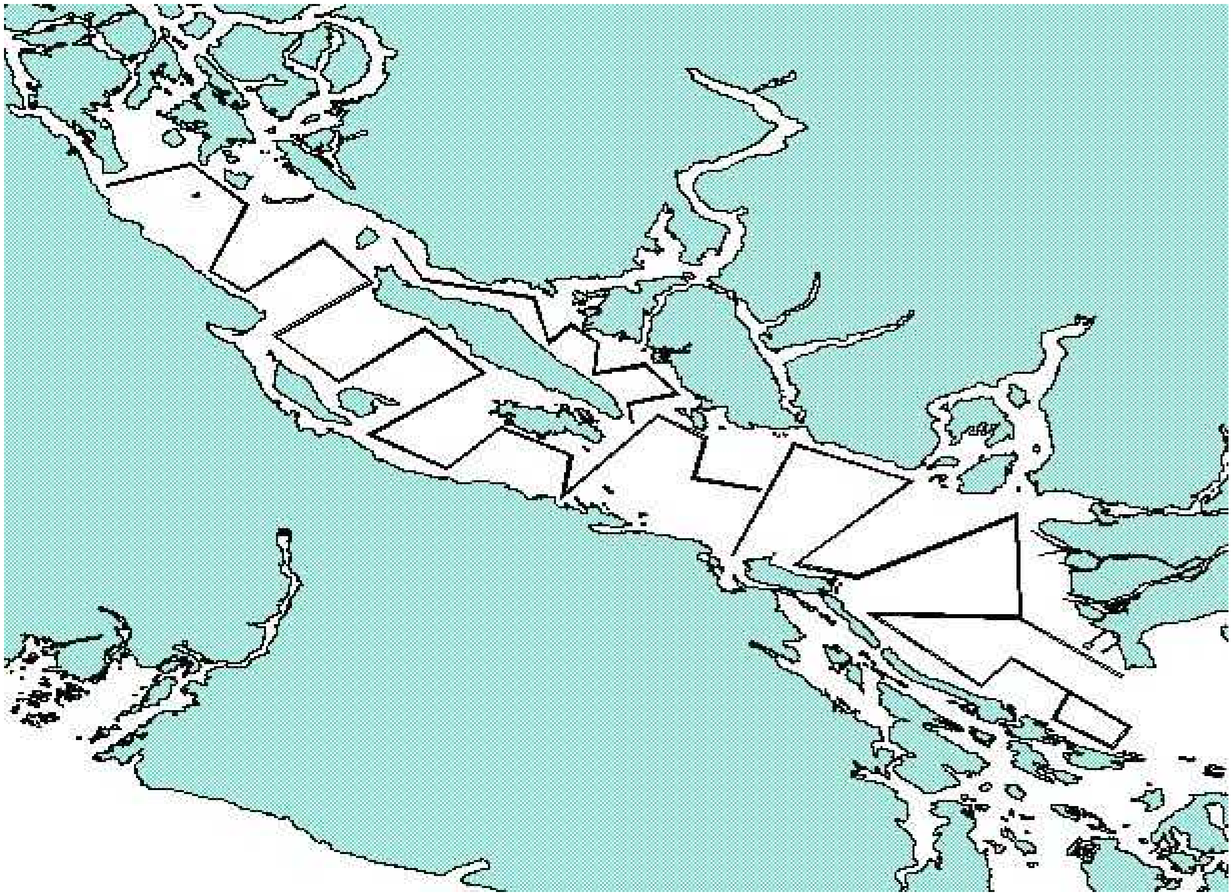

Figure 1 Survey track for annual trawl surveys in the Strait of Georgia, 1997 to 2001.

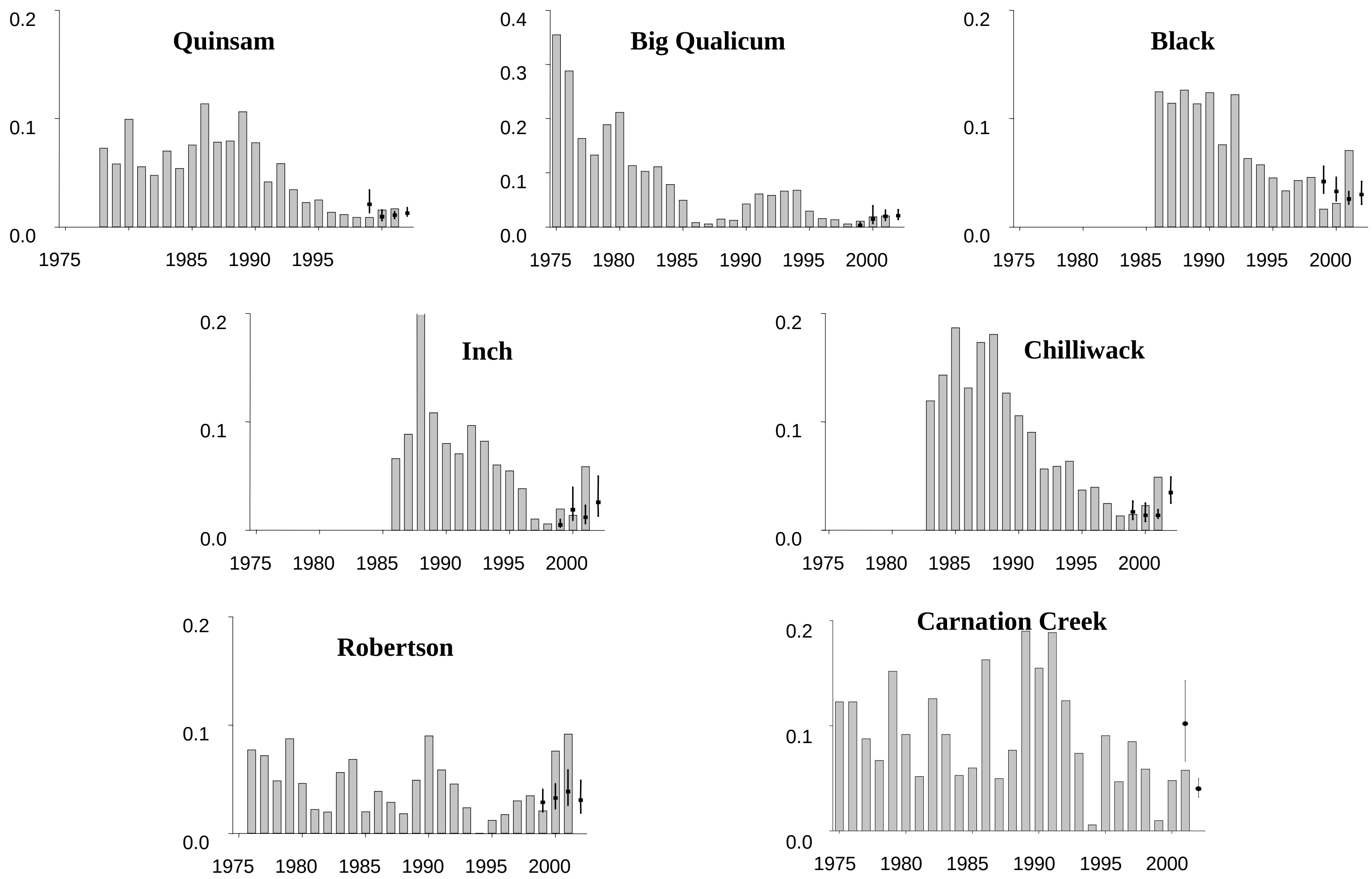

Figure 2 Marine survivals of southern BC coho. Forecasts since 1999 are shown as point symbols and bars, the latter indicating the 50% CL's.

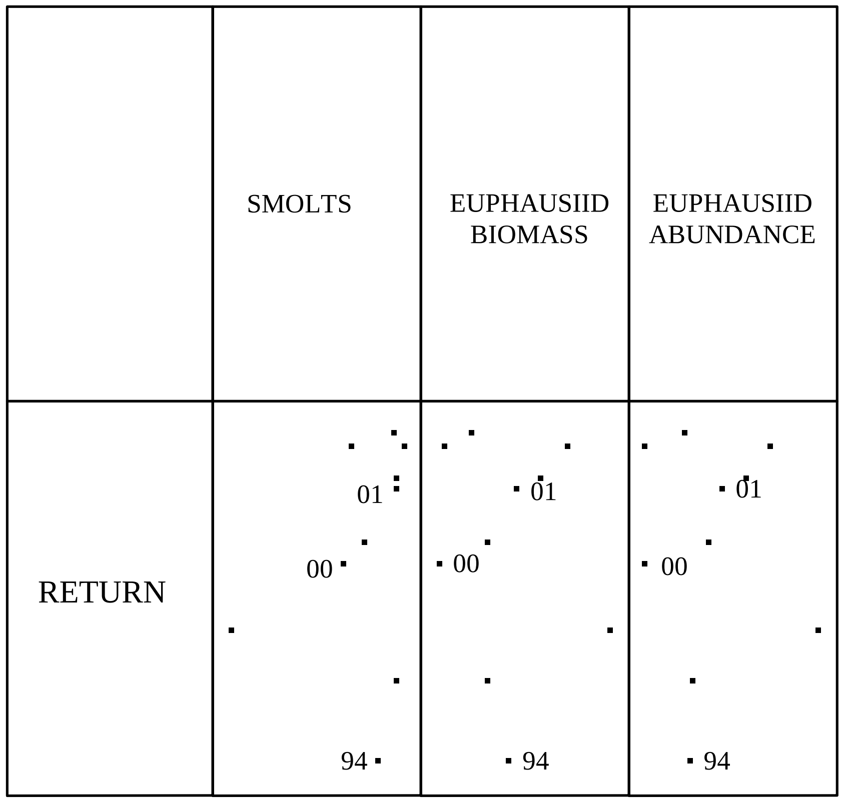

Figure 3 Scatterplots of the adult returns of Carnation Cr. coho and: number of Carnation smolts the previous year and biomass and abundance of 9-12mm *T. spinifera* in June to August of the previous year. All data are log transformed. Point labels indicate the return year.

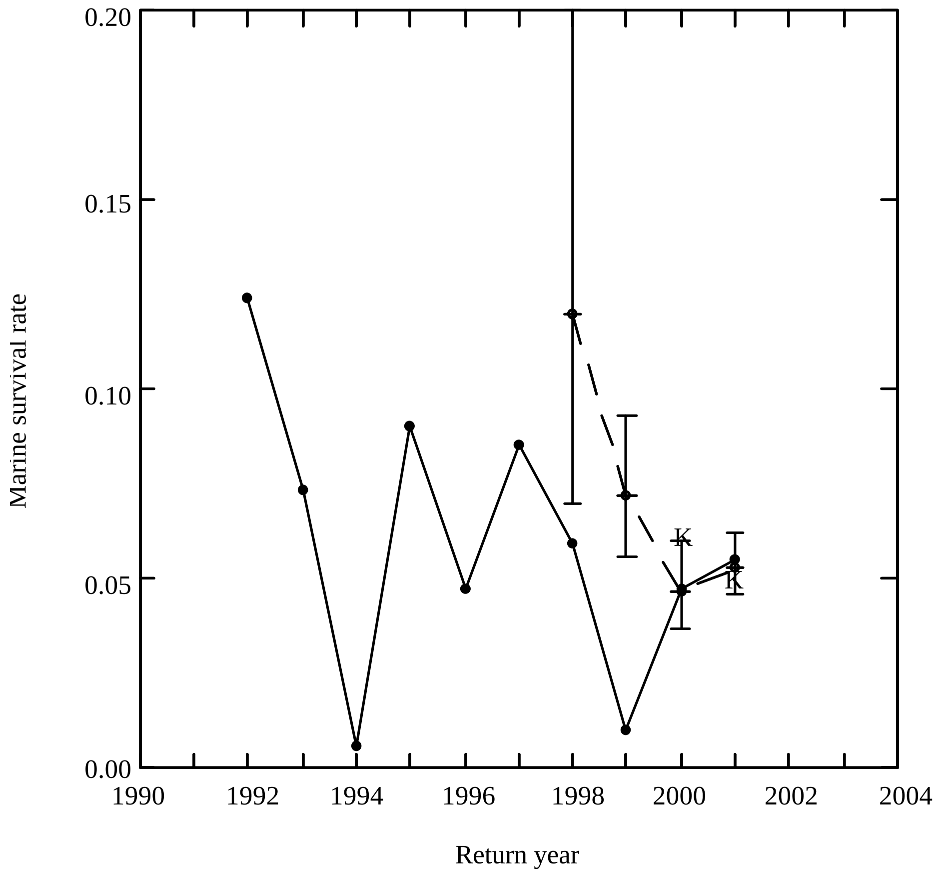

Figure 4 Results of retrospective analysis of forecasting accuracy of smolt-euphausiid regression for Carnation Cr. coho. Solid circles – observed survival rate. Open circles – predicted survival rate. Error bars – 95% CL of predicted value. K – observed marine survival rate for Kirby Creek coho.

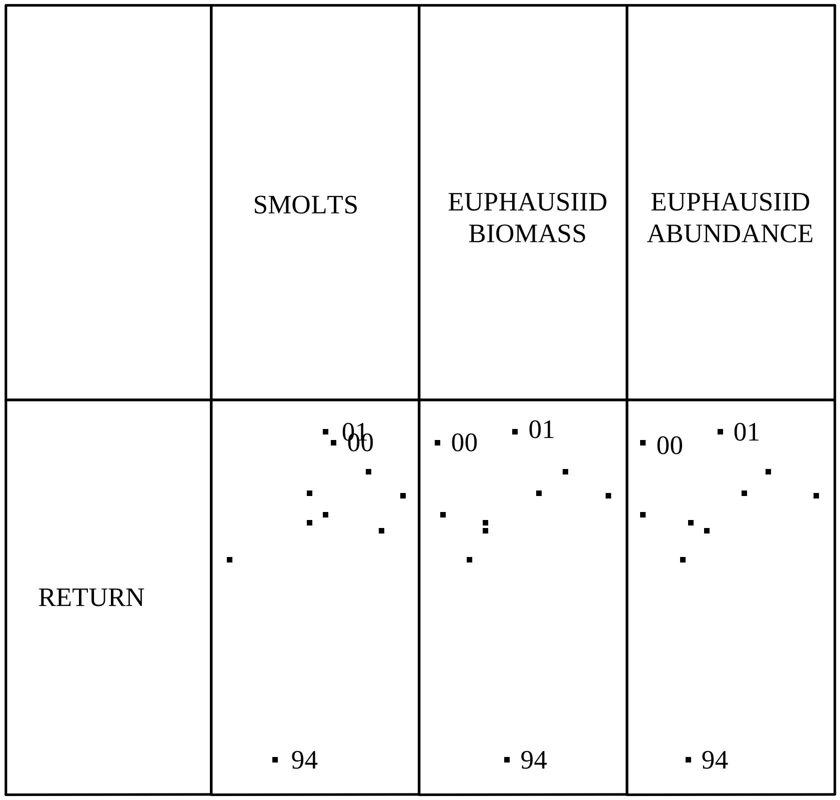

Figure 5 Scatterplots of the adult returns of Robertson Cr. Hatchery coho and: number of Robertson smolts the previous year and biomass and abundance of 9-12mm *T. spinifera* in June to August of the previous year. All data are log transformed. Point labels indicate the return year.

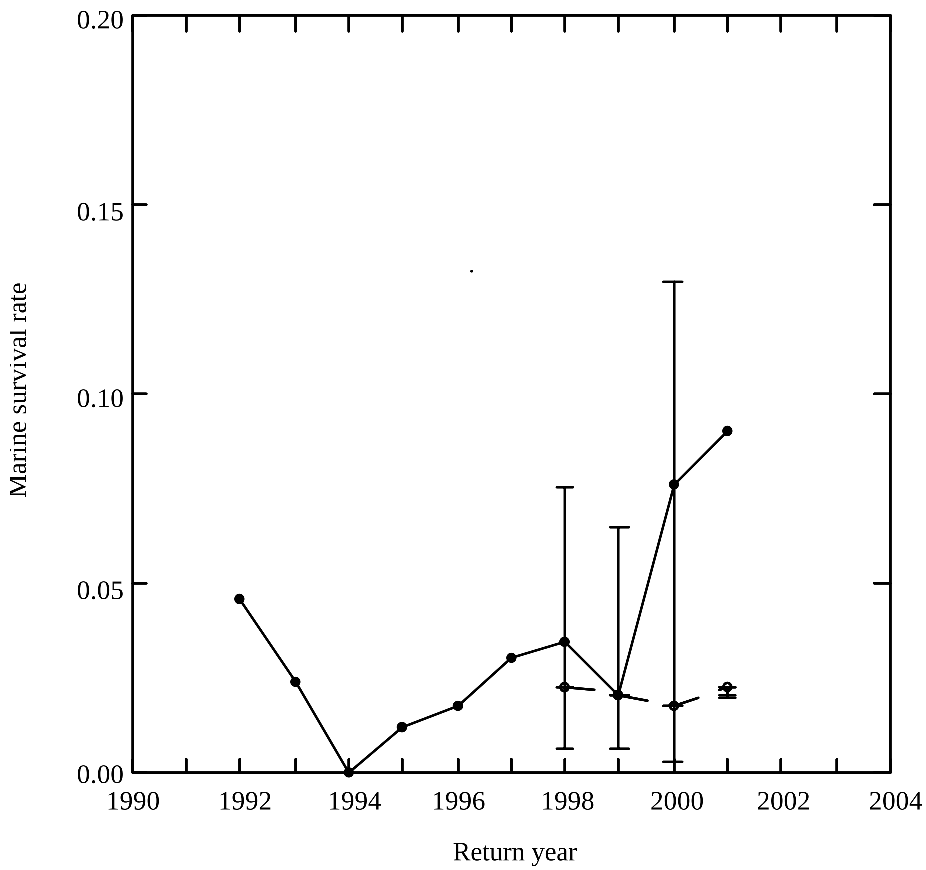

Figure 6 Results of retrospective analysis of forecasting accuracy of smolt-euphausiid regression for Robertson Creek Hatchery coho. Solid circles – observed survival rate. Open circles – predicted survival rate. Error bars – 95% CL of predicted value.

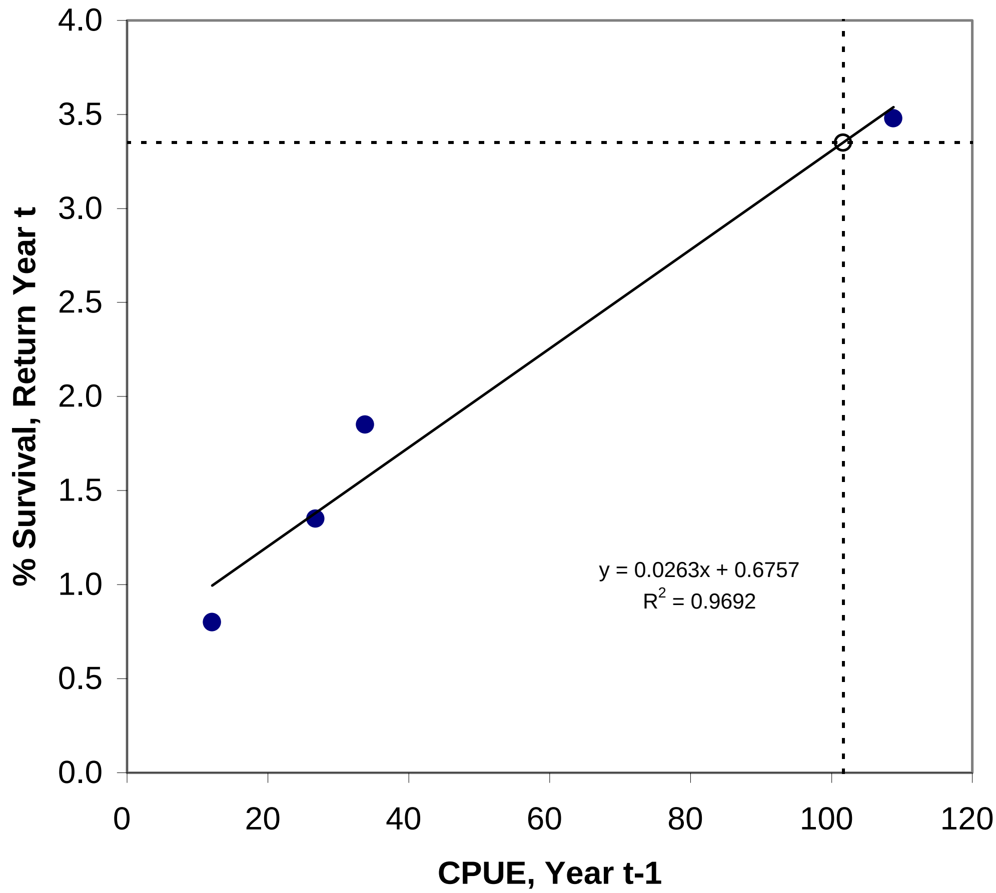

Figure 7 Regression of coho catches per hour (CPUE) in Strait of Georgia trawl surveys with mean marine survival of coho from Georgia Basin hatchery indicators: Chilliwack, Inch, Big Qualicum and Quinsam. The 2002 forecast is shown as an open symbol, based on the regression and a CPUE in 2001 of 102 coho/hour.

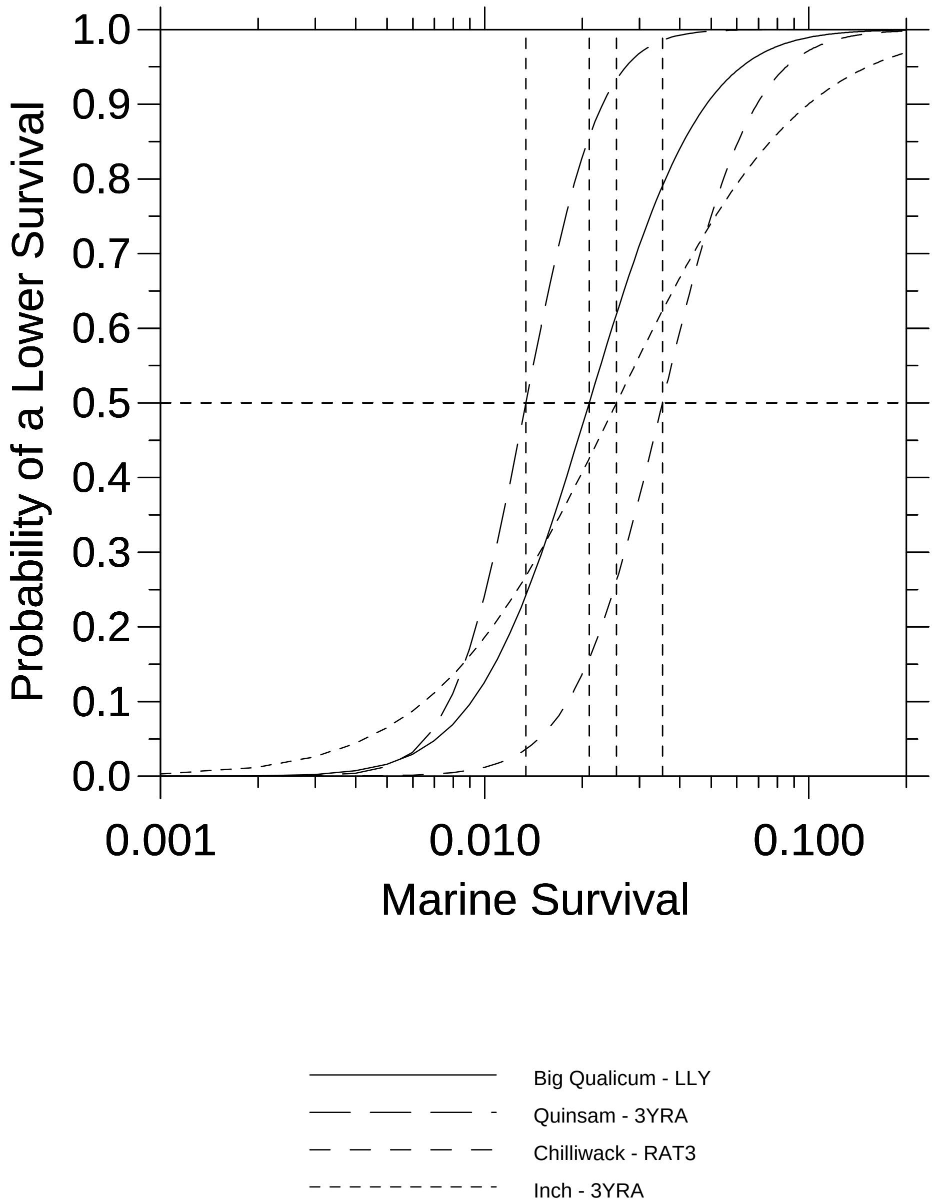

Figure 8 Confidence intervals around the time-series forecasts of marine survivals in 2002 for four hatchery indicators in the Georgia Basin.

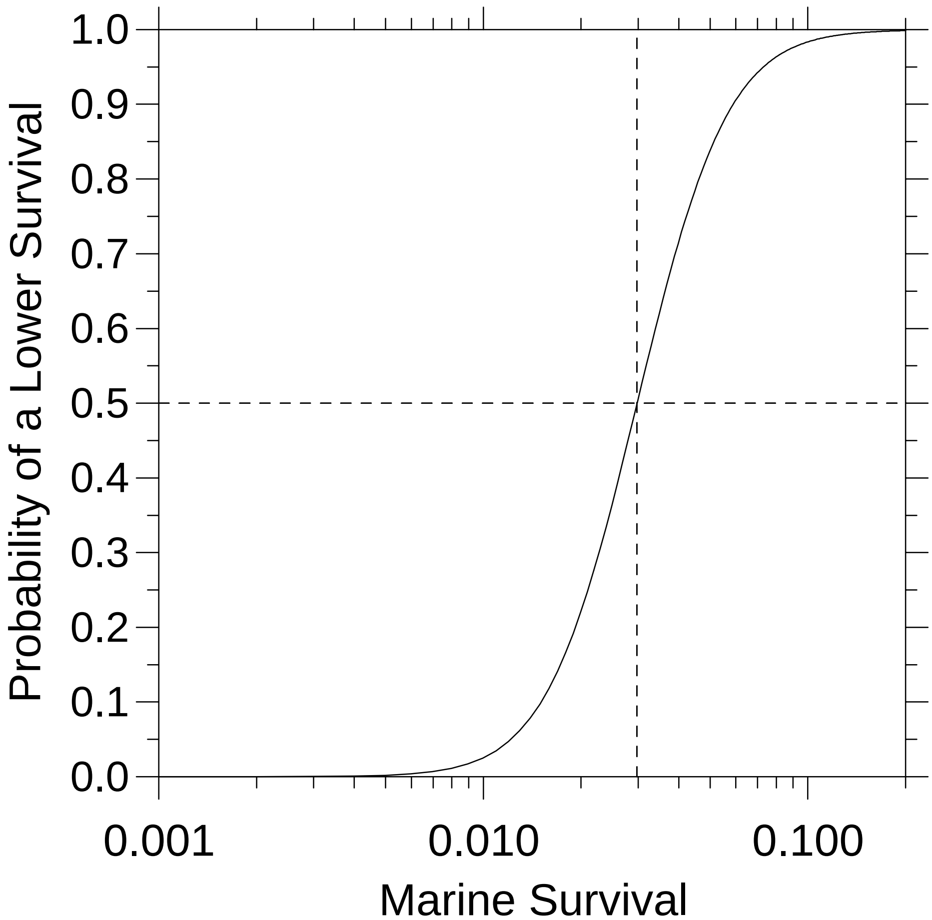

Figure 9 Confidence interval around the time-series forecast of marine survival in 2002 for the Black Creek wild indicator. The forecast is from the 3YRA time series model.

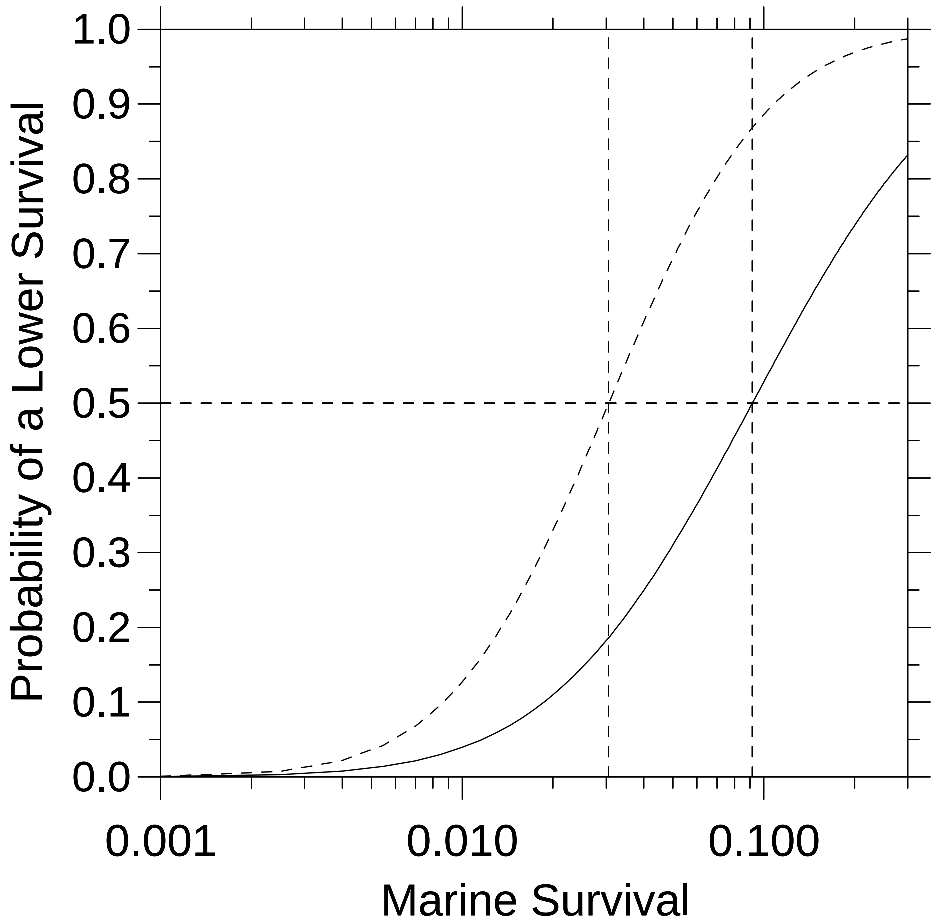

Figure 10 Confidence intervals around the time-series forecasts of marine survivals in 2002 for Robertson Hatchery (solid line) and the Carnation Creek wild stock (dashed line). Time series forecasts for Robertson and Carnation are from the LLY and 3YRA models, respectively.

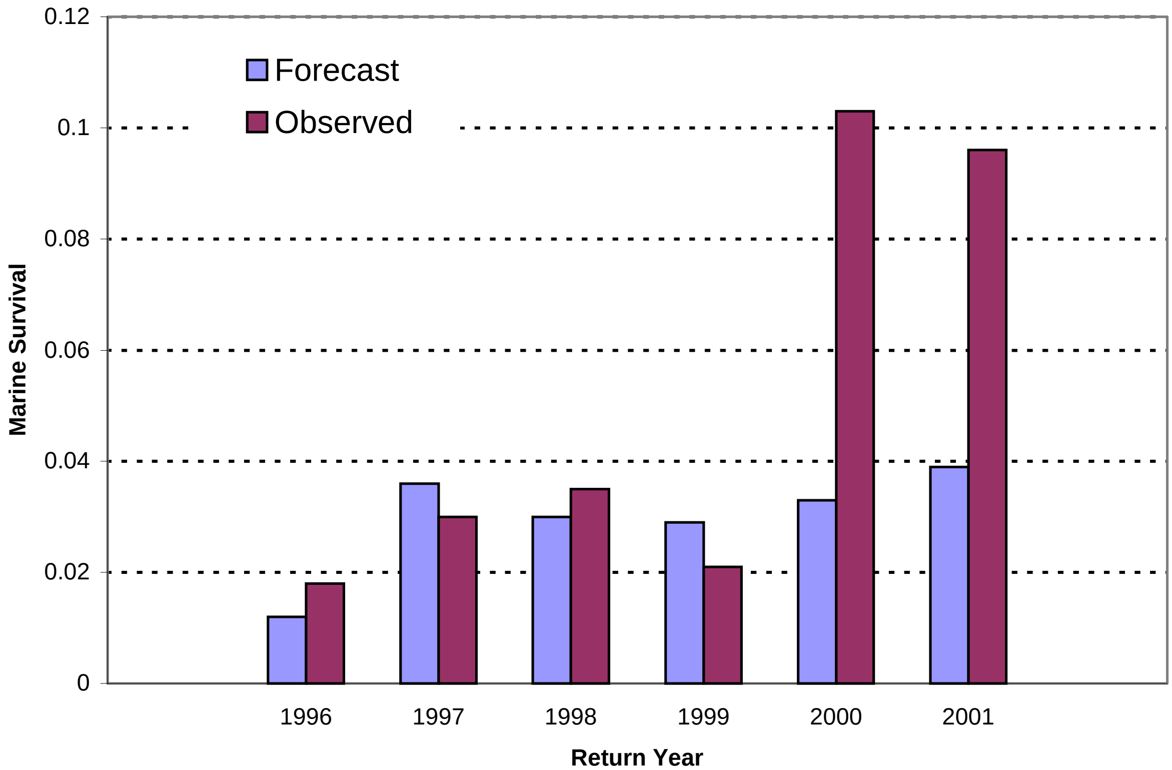

Figure 11 Sibling forecasts vs. observed marine survivals of Robertson Hatchery coho, 1996-2001.

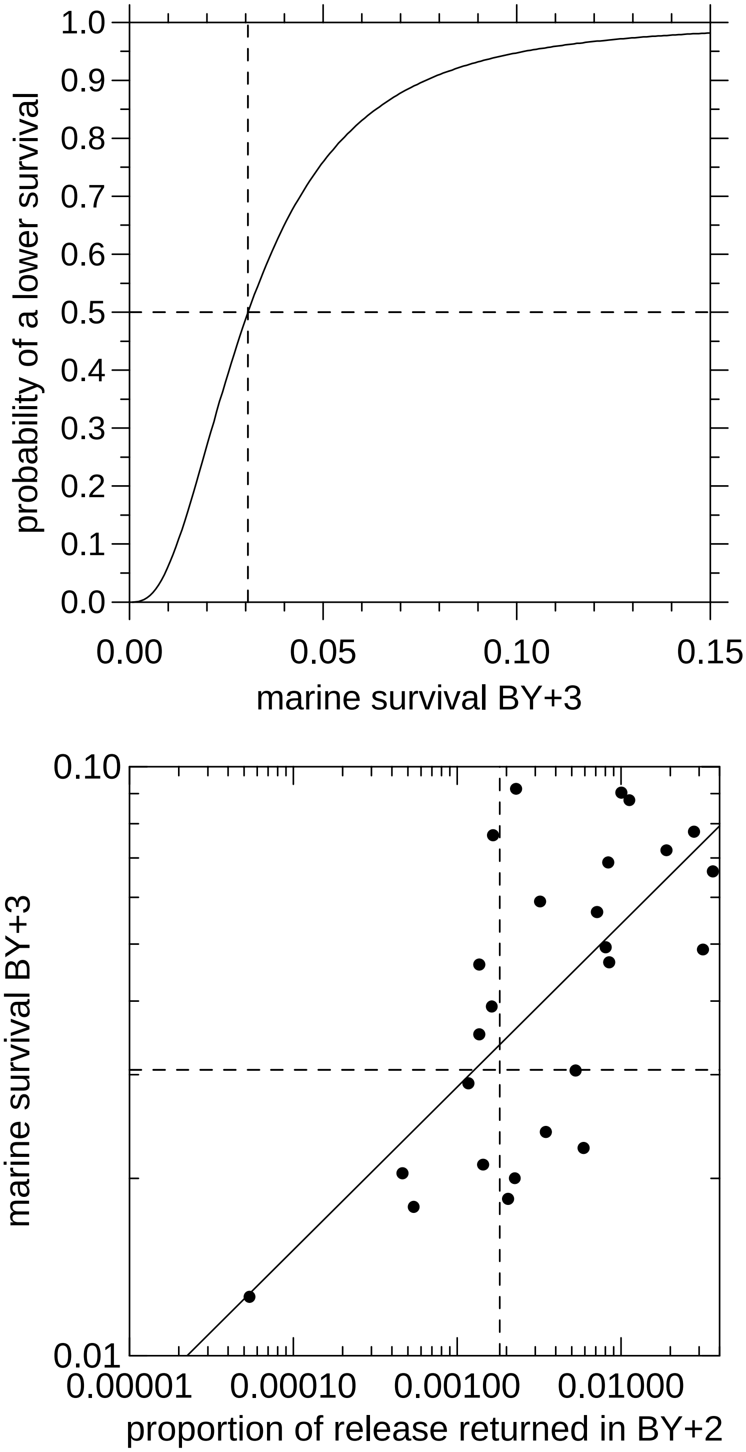

Figure 12 Survival forecast for Robertson Creek Hatchery coho in 2002 using the sibling model. The lower panel is the sibling relationship. The upper panel is the probability distribution for marine survival of the adult return in 2002.

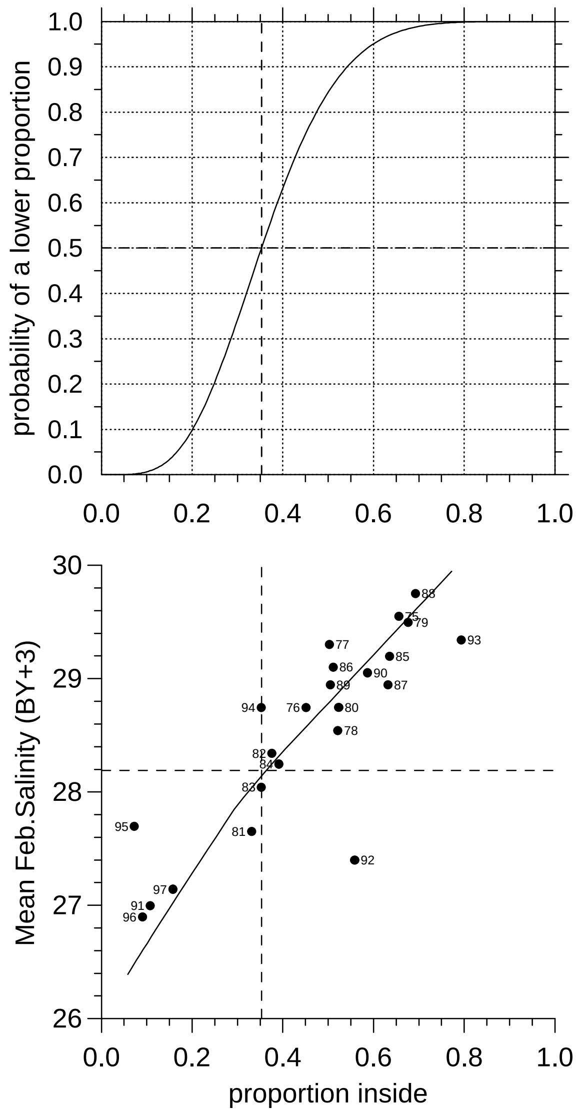

Figure 13 Predicting p_{inside} for 2002 using mean February salinities at Chrome and Sisters islands. The lower panel is the predictive relationship. The upper panel is the probability distribution for the point prediction.

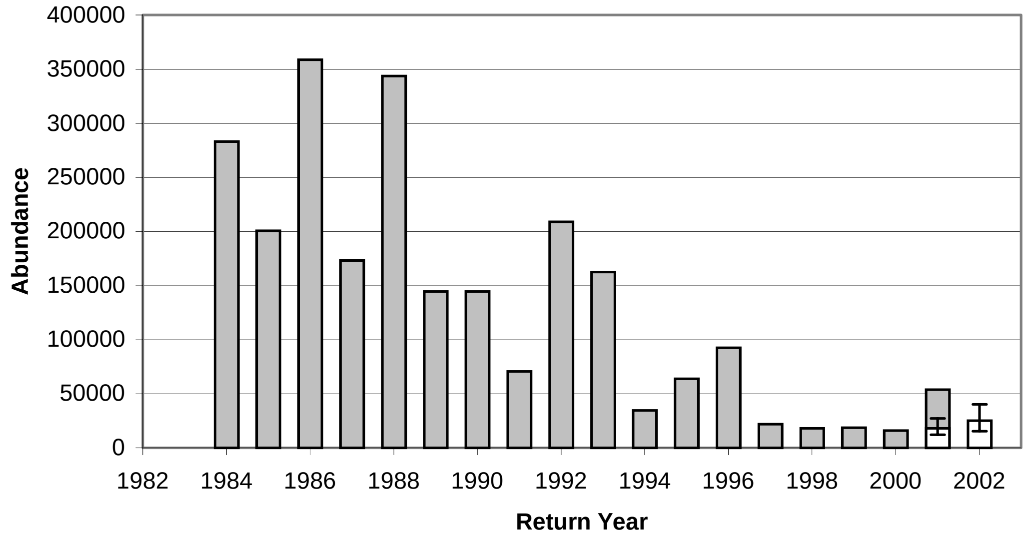

Figure 14 Estimated total abundance of Thompson River watershed coho from 1984 to 2001. The forecasts for 2001 and 2002 are shown with associated 50% CI's.