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Forecast for southern British Columbia coho salmon in 1999

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Abstract

This Working Paper documents forecasts of marine survival, abundance and distribution for the coho salmon of southern British Columbia (Thompson River, lower Fraser, Strait of Georgia, and west Vancouver Island).

Marine survival: Our recommendations for the marine survival forecast for the five hatchery indicators and one wild coho indicator are given in the following Table. Survivals are expected to remain poor for all Strait of Georgia wild and hatchery stocks and are forecast to be either unchanged or lower in 1999 compared to 1998 (following Table). Survival of Black Creek coho, the single wild indicator on the Strait of Georgia for which there is a forecast, is one of the survivals expected to be lower in 1999 compared to 1998. Nevertheless, survival rates appear to be substantially greater toward the north end of Georgia Strait compared to the lower mainland and the Fraser. CWT escapement data are not yet available for Thompson coho and consequently there is no forecast of marine survival for this aggregate. There are no indications in the magnitude of the escapement that survivals improved in 1998 and the forecast of abundance remains dismal. The forecast survival for wVI coho is slightly lower than in 1997 and 1998.

indicator	Model	$\hat{s}_{1999}$	(50% CI)	change relative to 1998
Big Qualicum	LLY	0.003	(0.0013–0.008)	same
Quinsam	LLY	0.021	(0.013–0.034)	same
Chilliwack	RAT3	0.017	(0.010–0.027)	lower
Inch Creek	LLY	0.005	(0.003–0.010)	same
Black Creek	3YRA	0.042	(0.031–0.056)	lower
Robertson Creek	sibling regression	0.029	(0.020–0.041)	lower

Abundance forecast: Without fisheries information, forecasting abundance is highly problematic, and because we are using time-series models, the forecast is dependent on the highly uncertain estimate of abundance in 1998. With those caveats the RAT3 forecast of the StG-Fr aggregate is 2.0×10^5 (50% CI: 1.5×10^5–2.8×10^5). This forecast portends a very worrisome further deterioration in the status of Strait of Georgia coho.

The LLY forecast for the wVI aggregate is 4.5×10^5 (50% CI: 3.1×10^5–6.5×10^5). This forecast is 77% of the overall average abundance of 5.9×10^5.

The abundance forecast for Thompson coho is for continued severe depression. Brood year escapements in the Thompson were very low and there is no indication that marine survival will improve either in the southern Strait of Georgia or the west coast of Vancouver Island. We conclude that it is unlikely that stock size will increase appreciably for either the North or South Thompson aggregate in 1999.

Distribution forecast: The predicted proportion of catch inside the Strait of Georgia (p_{inside}) should there be no fishing restrictions is 0.33 (50%CI 0.25–0.42), which can be characterized as a moderately strong outside distribution. The confidence interval suggests that an extreme outside year ($p_{inside} < 0.2$) is about as likely as a return to a "normal" distribution ($p_{inside}>0.4$).

Résumé

Le présent document traite des prévisions de la survie en mer, de l'abondance et de la répartition du saumon coho du sud de la Colombie-Britannique (rivière Thompson, bas Fraser, détroit de Géorgie et ouest de l'île de Vancouver).

Survie en mer : Nos recommandations relatives à la prévision de la survie en mer des cinq stocks d'élevage et du stock sauvage de saumon coho servant d'indicateurs sont présentées dans le tableau ci-après. Les taux de survie devraient demeurer faibles pour tous les stocks sauvages et d'élevage du détroit de Géorgie et l'on prévoit qu'ils demeureront inchangés ou diminueront en 1999, comparativement à 1998 (tableau). La survie du coho de Black Creek, le seul stock sauvage indicateur du détroit de Géorgie pour lequel nous disposons d'une prévision, est l'un de ceux dont le taux de survie prévu sera inférieur en 1999, par rapport à 1998. Le taux de survie semble cependant passablement plus élevé dans la partie nord du détroit de Géorgie, comparativement au lower mainland et au Fraser. Nous ne disposons pas encore des données sur les échappées obtenues par étiquettes à fils codés pour le coho de la Thompson et nous n'avons donc pas de prévision pour la survie en mer de ces stocks. L'importance des échappées n'indique pas qu'il y ait eu amélioration du taux de survie par rapport à 1998 et l'abondance prévue demeure extrêmement faible. Le taux de survie prévu pour le coho de l'ouest de l'île de Vancouver est légèrement inférieur à ceux de 1997 et 1998.

Indicateur	Modèle	$\hat{s}_{1999}$	(IC de 50%)	Écart par rapport à 1998
Big Qualicum	LLY	0,003	(0,0013–0,008)	inchangé
Quinsam	LLY	0,021	(0,013–0,034)	inchangé
Chilliwack	RAT3	0,017	(0,010–0,027)	inférieur
Inch Creek	LLY	0,005	(0,003–0,010)	inchangé
Black Creek	3YRA	0,042	(0,031–0,056)	inférieur
Robertson Creek	régression (cl. jumelles)	0,029	(0,020–0,041)	inférieur

Prévision de l'abondance : En l'absence de renseignements obtenus des pêches, la prévision de l'abondance s'avère très difficile et comme nous utilisons des modèles fondés sur des séries chronologiques, la prévision est dépendante des estimations fortement incertaines obtenues pour 1998. Si l'on fait abstraction de ces lacunes, la prévision RAT3 du groupe StG-Fr est de $2{,}0\times10^5$ (IC de 50%: $1{,}5\times10^5$–$2{,}8\times10^5$). Cette prévision indique une détérioration supplémentaire préoccupante de la situation du coho de détroit de Géorgie.

La prévision LLY du groupe wVI est de $4{,}5\times10^5$ (IC de 50% : $3{,}1\times10^5$–$6{,}5\times10^5$). Cette prévision correspond à 77 % de l'abondance moyenne générale de $5{,}9\times10^5$.

La prévision d'abondance du coho de la Thompson fait état du maintien d'un appauvrissement sévère. Les échappées dans la Thompson ont été très faibles et rien n'indique que la survie en mer s'améliorera que soit dans le sud du détroit de Géorgie ou

sur la côte ouest de l’île de Vancouver. Nous concluons qu’il est peu probable que les effectifs des stocks de la North ou de la South Tompson augmentent de façon appréciable en 1999.

Prévision de la répartition : La proportion prévue des captures à l’intérieur du détroit de Géorgie (p_{in}) en l’absence d’une limitation de la pêche est de 0,33 (IC de 50% : 0,25–0,42), ce qui peut être qualifié de répartition modérément forte en faveur de l’extérieur. L’intervalle de confiance porte à croire qu’une répartition extrême vers l’extérieur (p_{in} < 0.2) est pratiquement aussi probable qu’un retour à une répartition « normale »(p_{in}>0.4).

Table of Contents **page**

1. Introduction 10
2. Data Sources 10
3. Forecasting Models and Retrospective Analysis of Predictive Power. 11
 3.1 Forecasting models 11
 3.2 Retrospective analyses 12
4. 1998 Marine Survival Estimates 13
 4.1 Retrospective Analysis of Survival Predictors 14
 4.2 Biologically based forecast for wVI coho 14
 4.3 Marine Survival Rate Forecast 15
5. Forecast of distribution 15
6. Forecasts of abundance 16
 6.1 Estimation of abundance in 1998 17
 6.2 Forecast abundance in 1999 17
 6.3 Upper Fraser and Thompson coho 18
7. Conclusions 19
 7.1 Marine survival 19
 7.2 Abundance forecast 20
 7.3 Distribution forecast 20
8. References 21

Tables **page**

Table 1. Release and recovery summaries for the six indicator streams used to generate forecasts. 23

Table 2. Retrospective performance statistics for predictors of $\hat{s}_{smolt}$. Within each hatchery indicator the methods were compared over the same set of years. In the top section of the Table the number of observations in the comparison was determined by the requirement that the sibling regression data-set held at least nine observations. If in that comparison a time-series model outperformed the sibling regression then the comparison was restricted to the time-series models. These comparisons are shown in the bottom section of the Table. The 'best' model for each hatchery indicator is shaded. 26

Table 3. Forecast of age 3 return ($\hat{R}_3^{1999}$) and survival ($\hat{s}_{smolt}$) for 1996 brood year for the four Strait of Georgia indicators and Robertson Creek using sibling regressions. Data used are found in Table 1. The slope and intercept are for the sibling regression model (Equation 6). 27

Table 4. Forecasts of age 3 survival ($\hat{s}_{smolt}$) with confidence levels for the 1996 brood year, for the four Strait of Georgia hatchery indicators and one wild indicator and the wVI hatchery indicator. The predictions of the best performing models are shaded. 28

Table 5. Data used for the biologically based survival forecast for Robertson Creek coho. The euphausiid biomass is the average June to October biomass of *Thysanoessa spinifera* in Barkley Sound in the smolt year (BY+2). The marine survival data are from Table 1. 29

Table 6. Data used in forecasting catch distribution of Strait of Georgia coho salmon. The salinity time series is the average sea-surface salinity measured at Sisters Island and Chrome Island lighthouses in February of BY+3. 30

Table 7. Correlations between p_{inside} for the four hatchery stocks on the Strait of Georgia. N = 15 for all correlations. 30

Table 8. Forecast of p_{inside} for 1999 for Strait of Georgia hatchery indicators using the salinity model. Data used are in. 31

Table 9. Total stock size (N_h) for the four inside hatchery indicators and their proportions (p) of N_A, , the StG-Fr aggregate of wild stocks. Total stock size is the expanded recoveries of age 3 fish as recorded in MRP plus estimates of terminal FW harvest. 32

Table 10. Estimates of $\hat{N}_A$ for the StG-Fr aggregate. 32

Table 11. Total stock size (N_h) for the single outside hatchery indicators and its proportion (p) of N_A, the wVI aggregate of wild stocks. 33

Table 12. Forecasts of abundance for StG-Fr and wVI aggregates in 1999 ($\hat{A}_{1999}$), with retrospective analysis and confidence limits. The recommended models are shaded. 33

Table 13. Coho escapement time series for the eight North Thompson index streams.... 34

Table 14. Coho escapement time series for eight index streams in the South Thompson River drainage from 1975 to 1998. 35

Table 15. Coho escapement time series for eight additional index streams in the South Thompson River drainage from 1975 to 1998. 36

Table 16. Exploitation rate, escapement and total return for North and South Thompson average-streams. The marine survival and exploitation rates are averages of the Thompson indicator streams.......... 37
Table 17. Forecasts of average-stream total returns to the North and South Thompson for 1999 with their associated confidence intervals. Both forecasts were based on the 3YRA model.......... 37

Figures **page**

Figure 1. Marine survivals vs. return year for seven coho indicators in southern British Columbia. The forecast survivals for 1999 are shown with associated 50% CIs. The Thompson values are a composite of all available smolt release data. A 1999 forecast survival is not available for the Thompson. 38
Figure 2. Return and survival forecast for Robertson Creek coho in 1999 using the sibling regression model. The lower panel is the sibling relationship. The upper panel is the probability distribution for the predicted age 3 return. Returns can be converted to survival using the middle scale........ 39
Figure 3. Confidence intervals around the time-series forecasts of marine survivals for four hatchery indicators and Black Creek. 40
Figure 4. Marine survival at Robertson Creek vs. euphausiid biomass in Barkley Sound. The outlier (1994 return year) was excluded from the fitted line shown. 41
Figure 5. Predicting pinside for 1999 using average Chrome Island and the Sisters February salinities. The lower panel is the predictive relationship. The upper panel is the probability distribution for the point predictions. A February salinity of 28.07 was used........ 42
Figure 6. Abundance estimates for the Strait of Georgia+Fraser aggregate and the West Coast Vancouver Island aggregate of southern British Columbia coho. Values shown for 1998 are for estimates derived from each hatchery indicator and for all hatcheries combined (the overall p_h) for the period 1990 to 1997. For the StG-Fr aggregate the preferred estimate of 1998 abundance is shaded. The forecast abundances for 1999 with associated 50% CI are shown for both aggregates. 43
Figure 7. The ratio of the return to each hatchery to the estimated abundance of the StG-Fr aggregate. The overall proportion was calculated by summing the hatchery indicator abundances before calculating the ratio. 44
Figure 8. Probability plots for the abundance forecasts for StG-Fr and wVI aggregate abundance in 1999 using the recommended models. 45
Figure 9. Total returns to North and South Thompson aggregates from 1975 to 1998. The forecasts for 1999 with their 50% CI are shown. 46

1. Introduction

Forecasts of the marine survival rate, the ocean distribution and the ocean abundance of southern British Columbia coho in 1999 are presented in this Working Paper. The methods we used in developing the forecasts marine survival rate and ocean distribution are similar to those used in previous working papers (Holtby and Kadowaki 1998, Kadowaki et al. 1996; Kadowaki 1997).

2. Data Sources

Catch and escapement data for coded-wire tagged coho from the Big Qualicum River, Quinsam River, Chilliwack River, Inch Creek and Robertson Creek hatchery stocks and catches of Black Creek coho were obtained from the Mark Recovery Program (MRP) data base maintained at the Pacific Biological Station in Nanaimo, B.C. CWT'd smolt releases in 1997 from the Big Qualicum River, Chilliwack River, and Inch Creek facilities included fish whose left ventral and adipose fins had been removed. These doubly marked fish were <u>not</u> included in any calculations of survival. All hatchery coho were included in estimates of abundance. Escapement data for Black Creek was obtained from program sources in the Stock Assessment Division. Coho could not be retained in Canadian waters in 1998 as part of the conservation measures undertaken to protect Thompson coho. There were some exceptions in terminal areas where surpluses were identified. However, many fisheries proceeded. Coho that were caught were released with minimal harm.

CWT recovery data for 1998 are preliminary and may change once catch and escapement estimates are finalized. A full treatment of the 1998 season will be contained in a future PSARC paper. For forecasting purposes, an exploitation rate of 5% in Canadian fisheries was applied to all stocks. The exploitation rate in southern US fisheries was assumed to be half of the historic average rate. The exploitation rate in Alaskan fisheries was calculated using recovery data in MRP. Thus, the estimates of total exploitation rate must be viewed as preliminary.

Freshwater sport recoveries of CWT'd coho from the Chilliwack and Inch Creek hatcheries were added to the escapement rather than treated as catch to better represent the exploitation rate on wild stocks, which are not exposed to this intense terminal fishery. Unfortunately the age composition of the terminal sport catch was not estimated. To estimate recoveries at Chilliwack we first assumed that the no-pin rate observed at the hatchery (70 of 1223) was the same for LV/adipose- and adipose-clipped fish. The hatchery escapement of adipose clipped CWT'd age 3 coho was therefore 932. Adipose-clipped age-3 coho were 4.7% of the marked coho in the return to the hatchery and we assumed that the same proportion would apply to the age-3 coho taken in the sport fishery. Marked jacks (all would have been adipose clips) were 0.4% of the hatchery escapement. Assuming that jacks were equally likely to be caught in the sport fishery as age-3 coho means that of the 11,886 coho estimated caught in the terminal fishery approximately 557 were adipose-clipped age-3 coho. That estimate is reduced to 554 if we assume that jacks are three-times as likely to be caught as age-3 fish. Our estimate of the escapement of adipose-clipped only coho is 1485.

Estimating the number of Inch Creek hatchery fish taken in the terminal sport fishery is not possible with certainty. Terminal harvest of two adults and two jacks was permitted regardless of marking and no records were taken of the age composition. The fishery also involved returns from releases to the Stave River and the Nicomen Slough. We assumed that the return was proportional to release and the 90% of the fish taken were age-3 adults. We estimated that 912 of the reported harvest of 1062 were age-3 Inch Creek coho and that the escapement of that stock was 3,712.

Salinity data for the two lighthouses in the Strait of Georgia were obtained from C. Perkins, Institute of Ocean Sciences, Sidney, BC.

3. Forecasting Models and Retrospective Analysis of Predictive Power.

3.1 Forecasting models

In this paper we forecast marine survival rates (s), catch distribution (p_{inside}) and stock size or abundance (A). All of these variables are forecast using four quasi-time series models. In each model the variable being forecast (v_t) is first transformed so that

$$Z_t = \Im(v_t) \qquad (1)$$

The Log transformation was used for abundance. The Logit transformation[1] was applied to proportions such as s or p_{inside}. The four models can then be described as follows:

mnemonic	model	Equation
LLY ("Like Last Year")	$Z_{t+1} = Z_t + \varepsilon_t$	(2)
3YRA (3-year average)	$Z_{t+1} = \dfrac{\sum_{k=t-2,t} Z_k}{3} + \varepsilon_t$	(3)
RAT1 (1 year trend)	$Z_{t+1} = \dfrac{Z_t^2}{Z_{t-1}} + \varepsilon_t$	(4)

[1] $Z_t = \log \dfrac{v_t}{1-v_t}$

mnemonic	model	Equation
RAT3 (average 3-year trend)	$Z_{t+1} = \frac{\sum_{k=t-2,t} Z_k / Z_{k-1}}{3} Z_t + \varepsilon_t$	(5)

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 the purpose of 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)
project trends?	NO	LLY	3YRA
	YES	RAT1	RAT3

Marine survival rates were also predicted using a “sibling-regression” model, where the total return of age-3 fish (R_3^{BY+3}) is predicted from the observed age-2 male escapement (R_2^{BY+2}, ‘jacks’):

$$\log_e R_3^{BY+3} = b \log_e R_2^{BY+2} + a \tag{6}$$

Survival (s_{smolt}) was then calculated by dividing the age-3 return by the number of smolts released (N_{smolt}).

Catch distribution or the proportion of the catch caught in waters inside the Strait of Georgia (p_{inside}) was estimated using the model:

$$Logit(p_{inside}) = bS + a \tag{7}$$

where S is the average February surface salinity at Chrome Island and Sisters in BY+3[2]. Confidence limits around forecasts in the case of the latter two models were determined using linear regression analysis.

3.2 Retrospective analyses

To compare the performance of the forecast models we computed both the Root Mean Square Error (*RMSE*):

[2] BY is the brood year. The progeny of fish spawning in year 1 are caught and spawn in year 4 or BY+3.

$$RMSE = \sqrt{\overline{\left(v_{observed,t+1} - v_{predicted,t+1}\right)^2}} \qquad (8)$$

and the Mean Absolute Deviation (*MAD*):

$$MAD = \left|\overline{\left(v_{observed,t+1} - v_{predicted,t+1}\right)^2}\right| \qquad (9)$$

Note that this calculation is performed in the variable space and not in the transformed (equation 1) space.

For models involving regressions (either equation 6 or 7), values of *RMSE* and *MAD* were compiled by fitting the model using only the first nine observations and forecasting the tenth year. The tenth year was then added to the data set, the model refit and the eleventh year forecast, and so on. In this way we assessed the predictive power of the model and not its fit to the data. For comparison of the performance of all models used, the *RMSE* and *MAD* values were computed over the largest set of years common to all of the forecasts. For the Robertson Creek indicator only BY1992 was a clear outlier to the sibling relationship and it was excluded from the calculation of the sibling regression, but not from the calculations of *RMSE* and *MAD*.

4. 1998 Marine Survival Estimates

Marine survival rates for the five hatchery indicators and Black Creek, a wild indicator, are presented in Table 1 and Figure 1. Survival rates at Big Qualicum, Inch Creek and Chilliwack were lower in 1998 than in 1997. Survival rates at Quinsam and Black Creek, the northern most indicators in the Strait of Georgia, and at Robertson Creek increased in 1998 compared to 1997 (Figure 1). Preliminary indications of escapement to streams around the Strait of Georgia are variable but suggest that survivals of wild coho were likely poor in the southern Strait and the lower Fraser. We think it unlikely that the survival of wild coho is as poor as it is at hatcheries but other than Black Creek we have no data that would allow a test of this.

Survival forecasts for 1998 were prepared for four of the hatcheries we consider in this Working Paper (Holtby and Kadowaki 1998). The survival rate was lower than predicted at Big Qualicum but higher than predicted at Chilliwack, Quinsam and Robertson Creek (see following Table). The observed survival was within the 50% CI for three of the indicators and only slightly above at the remaining one.

indicator	forecasting model	$\hat{s}_{1998}$	50% CI for *s*	s_{1998}
Big Qualicum	RAT3	0.007	0.002 – 0.02	0.003
Chilliwack	RAT3	0.019	0.012 – 0.03	0.021
Quinsam	LLY	0.012	0.008 – 0.018	0.021
Robertson Creek	sibling regression	0.030	0.021 – 0.043	0.038

4.1 Retrospective Analysis of Survival Predictors

Comparison between the four time series models and the sibling regression model is complicated by the varying number of years in each data set. For Chilliwack and Inch Creek hatcheries the size of the data set was very limited because of the requirement to include at least 9 years of data in the sibling regressions. We first did a comparison of the sibling regression model and the time-series models. If the best performer in that comparison was a time series model then the time-series models were compared further using the longer time series.

Performance measures are summarized in Table 2 for the six indicator stocks. When the comparison between models was restricted to the time period where there were at least nine cases in the sibling regression models then either the RAT3 or RAT1 model performed best in the Strait of Georgia hatchery indicators, although the LLY model also performed well. The Sibling Regression model performed best at Robertson Creek. The relative performance of the LLY model improved when the time period was expanded to include all available data for the Strait of Georgia hatchery indicators (Table 2). The 3YRA model was the best performer for survival at Black Creek where survival has been nearly constant for the past three years (Table 1). The recommended model for each indicator is shown in the following Table.

indicator	recommended model
Quinsam	LLY
Big Qualicum	LLY
Chilliwack	RAT3
Inch	LLY
Black Creek (wild)	3YRA
Robertson Creek	Sibling Regression

4.2 Biologically based forecast for wVI coho

Marine survival of Carnation Creek coho appears related to early-ocean growth rates (Holtby et al. 1990), which are probably dependent on the amount of available food. Although juvenile coho feed on many species of zooplankton in their first few months in the ocean, euphausiids are the most important food item (Healey 1978; Petersen et al. 1982; Brodeur 1989; Brodeur and Pearcy 1990; Morris and Healey 1990; Brodeur et al. 1992). Euphausiid populations within Barkley Sound have undergone marked declines in recent years (RWT, unpubl. data) which prompted us to examine the relationship between the abundance of *Thysanoessa spinifera* in Barkley Sound in the smolt year with marine survival of Robertson Creek coho.

Collection and processing protocols for euphausiids are fully described in Tanasichuk (1998). The measure of abundance used here is the average biomass/m^2 (dry weight) during June through October of the smolt year (BY+2) of animals ranging in total length from 9 to 12 mm. This is the size range of susceptibility to juvenile coho (Petersen et al.1982). A total of seven observations were available (Table 5).

After appropriate transformations of the Robertson Creek marine survival data (Table 1) and the euphausiid biomass data (Table 5) we found a suggestive relationship between survival and biomass (Figure 4). The 1991 brood year is a clear outlier. Mackerel incursions into Barkley Sound in 1993 are the suspected cause of near-zero survival in coho and chinook. Excluding that year there is a marginally significant relationship between euphausiid biomass (BM_e) and coho survival (s):

$$Logit(s) = 0.459 \log(BM_e) - 5.758$$
$$(N = 6;\ \text{adj. } r^2 = 0.44;\ P < 0.1)$$

We included this predictor here because it leads to a different and considerably lower forecast for 1999 survival than the sibling regression and time-series models.

4.3 Marine Survival Rate Forecast

Survival forecasts and associated confidence intervals are shown for the sibling regressions in Table 3 and for the time-series models in Table 4. The survival forecasts made by the best performing model and associated 50% confidence intervals are presented in the following Table.

indicator	model	$\hat{s}_{1999}$	(50% CI)
Big Qualicum	LLY	0.0032	(0.0013–0.0079)
Quinsam	LLY	0.021	(0.013–0.034)
Chilliwack	RAT3	0.017	(0.010–0.027)
Inch Creek	LLY	0.005	(0.0027–0.010)
Black Creek	3YRA	0.042	(0.031–0.056)
Robertson Creek	sibling regression	0.029	(0.020–0.041)

The survival outlook for the hatcheries on the Strait of Georgia and in the lower Fraser is mixed but generally poor. Survivals at Big Qualicum and Inch Creek are expected to be considerably lower than 1%. The survival of Black Creek coho is expected to remain around 4%, where it has been for the past three years. Survival at the single outside indicator is expected to be lower than in recent years.

The biologically based predictor for wVI, introduced in Section 4.2, gives a survival forecast of 0.0153 (50% CI: 0.011–0.021). While this predictor is based on a short time-series, it is sufficiently lower than the conventional forecasts to warn against complacency for wVI coho originating in Barkley Sound.

5. Forecast of distribution

Variable proportions of the catch of coho originating the coho producing systems around the Strait of Georgia are taken in the sport, troll and net fisheries that have operated within the Strait (Kadowaki 1997; Simpson et al. 1997). Distribution is expressed as the proportion of the catch of hatchery indicator stocks taken in fisheries wholly within the Strait of Georgia (p_{inside}). There was no catch of coho in British Columbia during 1998. The estimated coho mortality in sBC amounted to an exploitation rate between 3% and 5%. Consequently, there is no estimate of p_{inside} for 1998 and the time series models that were developed in 1998 cannot be applied (Holtby and Kadowaki 1998). However, we note that the salinity model outperformed the time-series models by a large margin.

Surface salinity at two stations located in the central Strait of Georgia (Sisters and Chrome Island) are correlated with p_{inside}. Salinity in February of the year of return (brood year + 3) is the best predictor of p_{inside}. In Kadowaki (1997), the mean of the Chrome Island and Sisters Island February salinities was used to generate the distribution forecast, while in Kadowaki et al. (1996) and Holtby and Kadowaki (1998) the salinity at Chrome Island was used. We have reverted to the average of Chrome Island and Sisters. The differences between the predictions are small and of no practical significance.

Data used in the forecast are given in Table 6. Because of the high correlation between the catch distributions of the hatchery indicators (Table 7) we have forecast only the average distribution. At the time of writing, salinity was available only to the third week of February. With the record amount of rainfall that the region has seen in the past month it is possible that the eventual February salinity will be lower than the value available to us. Where GSsal is the average of the average February salinity at Chrome Island and Sisters:

$$\text{logit}(\hat{p}_{inside}) = 1.002\,GSsal - 28.9$$

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

Figure 5 shows the fitted relationship and a probability plot of the confidence interval. Confidence levels are tabulated in Table 8. A predicted value of 0.329 could be characterized as a moderately strong outside distribution. The confidence interval suggests that an extreme outside year ($p_{inside} < 0.2$) is about as likely as a return to a “normal” distribution (p_{inside}>0.4). Although there is a tendency to overestimate p_{inside} when its value is small (Figure 5), the preliminary salinity value is well above the low values (27‰) associated with strong outside distributions and marked over-prediction.

6. Forecasts of abundance

In southern British Columbia, all fisheries were managed to eliminate coho mortality wherever possible and to minimize it where not. Fisheries that were permitted were assigned mortality[3] ceilings based on forecasts of abundance of Strait of Georgia–Fraser (StG-Fr) and west Vancouver Island (wVI) stock aggregates. The StG-Fr aggregate includes stocks originating in streams draining into the Strait of Georgia and Johnstone Straits, including the Fraser and Thompson Rivers. The wVI aggregate is comprised of stocks on the West Coast of Vancouver Island. Holtby and Kadowaki (1998) forecast abundance for these aggregates using fishery mortality (catch), estimates of the stock composition of the catch and estimated mean exploitation rates. A similar method was used to forecast the abundance of coho in the WCVI troll fishing area (Kadowaki et al. 1996; Kadowaki 1997). A similar reconstruction could not be done for 1998 fisheries because there was no catch.

Our method for estimating abundance of the aggregate (A) in 1998 depends directly on past estimates of abundance. Estimates of total stock size (N_t) for individual hatcheries

[3] Mortality is the product of an assumed mortality per encounter and an encounter rate estimated from observation.

were made for the five indicator hatcheries. The ratio p_{ij} , was then calculated for each hatchery i in every year j possible:

$$p_{ij} = \frac{N_{ij}}{A_j}$$

The abundance in 1998 was then estimated for each hatchery i and for the sum of all hatcheries as:

$$A_i = \frac{N_h}{p_i}$$

where p_i is an average taken over either the entire time series or a recent period. This method assumes that past estimates of A and N_i were accurate.

6.1 Estimation of abundance in 1998

The ratio of hatchery stock size to the estimated total abundance of StG-Fr coho was more variable prior to 1990 than between 1990 and 1997 (Table 9; Figure 7), except for Inch Creek hatchery where the ratio has been roughly constant since 1985. Estimates of the 1998 StG-Fr abundance made using the average (1990–1997) ratios for individual hatcheries and for all four hatcheries summed range from 5.2×10^4 to 7.0×10^5 (Table 10). We have chosen the value estimated from the overall proportion (3.15×10^5) as the 1998 estimate of StG-Fr abundance. That abundance is greater than the 1998 forecast (2.4×10^5; Holtby and Kadowaki 1998) but within the 50% CI (1.8×10^5–3.3×10^5). Preliminary estimates of escapement to the region suggest to us that the estimate generated from the return to Big Qualicum is too low, while the estimate generated from the returns to Chilliwack may be too high. Of the three remaining estimates the smallest was generated from the overall return. This estimate was selected because it is the most conservative. Strong returns to many wVI streams suggest that the single estimate of wVI abundance in 1998 (4.5×10^5) is at least plausible. That estimate is considerably greater than the forecast for 1998 of 1.8×10^5 (50% CI: 1.3×10^5–2.5×10^5).

6.2 Forecast abundance in 1999

The four time series models were used to forecast abundance in 1999 for StG-Fr and wVI aggregates. In the period beginning in 1993 when abundance of the StG-Fr aggregate was clearly trending downward (Figure 6), the "best" model continued to be the RAT3 model (Table 12). With this model the forecast StG-Fr abundance is 2.0×10^5 (50% CI: 1.5×10^5–2.8×10^5; Table 12). A probability distribution of this forecast is shown in Figure 8. For the wVI aggregate the LLY model was the best performer over the period 1993-1998. The forecast abundance using this model is 4.5×10^5 (Table 12). A probability distribution of this forecast is shown in Figure 8.

6.3 Upper Fraser and Thompson coho

Although coho returning to the upper Fraser/Thompson are part of the StG-Fr stock aggregate, they are considered separately because of the role they played in determining salmon fisheries management in southern BC during 1998.

We restricted ourselves to the North and South Thompson drainages. Escapement data from other areas of the upper Fraser are of lower quality and the North and South Thompson aggregates were identified during the 1998 PSARC reviews as the main southern coho stocks of concern. From the available time series of visual escapement data we selected streams that were not enhanced and for which there were at least 19 annual escapement estimates (out of a possible maximum of 24). The survey effort expended in many systems during 1998 exceeded the effort given in previous years. We therefore adjusted our escapement estimates for 1998 to reflect historical survey efforts[4]. Escapement estimates for 8 streams in the North Thompson drainage (Table 13) and 16 streams in the South Thompson drainage (Table 14; Table 15) extend from 1975 to present. The exploitation rate and marine survival estimates are averages of all available data for Thompson indicators[5]. Survival rate estimates are for smolt releases only. An exploitation rate of 0.05 for Canadian fisheries was assumed for 1998. Thompson coho are exploited in southern US fisheries. For 1998 we assumed the exploitation rate was half of the historical average of 0.11. No CWT recoveries in the escapement were available at the time of writing. All data from 1998 are preliminary and are subject to revision. For the period 1975 to 1986 we used the average of the first five years of the measured exploitation rate. Data from prior to 1998 are from Irvine et al. (1999).

The escapement time series were manipulated to produce an "average-stream" escapement within each drainage. First, the escapement (E) in each stream i was scaled to the maximum escapement recorded in that stream across all years t:

$$p_{i,t} = \frac{E_{i,t}}{\max(E_i)} \qquad (10)$$

Then the $p_{i,t}$ were averaged across streams i within each year t to give a time series $p_{\bar{i},t}$ or p_{max}. The average stream escapement was constructed by multiplying p_{max} by the average across the i streams of $\max(E_i)$. Total returns could then be estimated using the exploitation rate time series. The resulting escapement and return time-series are shown in Table 16. The time-series models (equations 2 to 5) were used to forecast the 1999 return. The forecast from the best performing of these models over the period 1986 to 1998 was chosen. The North and South Thompson were forecast separately.

Escapement in 1998 relative to the brood year of 1995 was varied but in aggregate was considerably improved in the North Thompson but somewhat worse in the South Thompson (Table 13 to Table 15; Figure 9). The apparent failure of the South Thompson aggregate to respond more strongly to the near cessation in harvest is very worrisome, particularly since escapement in 1996 was the lowest yet observed in both Thompson drainages.

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[4] A detailed examination of this bias is presented in Irvine et al. (1999)

[5] 1987–1993: Eagle River; 1994–1995: Salmon River; 1995-1997 Louis & Lemieux Creeks.

The temporal pattern in total stock size is far from encouraging (Table 16; Figure 9). The substantial increase in escapement to the North Thompson appears to have been a transfer of catch to escapement with total stock size remaining roughly constant compared to 1997 and the brood year 1995. Total stock size of the South Thompson average-stream in 1998 was unchanged from 1997 but less than half that of the brood year.

In retrospective analyses the averaging models (LLY and 3YRA) considerably outperformed the ratio models in forecasts of total return, and the 3YRA model was the model of choice. Forecasts for the North and South Thompson aggregate are detailed in Table 17. The forecast total return to both areas is around 20% of the average total return and in both areas slightly more than the brood return. The forecast average-stream return for the North Thompson is 108 (50% CI: 64–181). Over the period 1975 to 1998 the average escapement was 188 and the average maximum escapement was 420. The forecast average-stream total return for the South Thompson average-stream is 77 (50%CI:48–124). Over the period 1975 to 1998 the average escapement was 141 and the maximum escapement 320. In both areas the forecast total return is around 55% of the past average escapement.

We have no analytical escapement target or standard for Thompson coho. If the period 1983 and 1991 were used to define a desirable escapement, then the forecasts for 1999 represent approximately 15% of such a target for the South Thompson and 20% for the North Thompson.

Measured marine survivals of Thompson indicators are difficult to interpret because there are no continuous time-series. However, marine survival appears to have declined (Figure 1), and escapement to the Thompson would suggest that there have been wide-spread declines in the survival of Thompson wild coho, although the effects of FW habitat loss cannot be discounted. Marine survivals for the Strait of Georgia indicators are not expected to improve in 1999. Brood year escapements in the Thompson were very low. These two factors make the conclusion that the outlook for Thompson coho in 1999 is critically poor a necessary one.

7. Conclusions

7.1 Marine survival

Our recommendations for the marine survival forecast for the five hatchery indicators and one wild coho indicator are given in the following Table. The survival outlook for the inside hatcheries is mixed but generally poor, and there is no indication that an already bleak situation will improve in 1999. Survivals at Inch Creek and Big Qualicum are expected to be considerably lower than 1%. Survivals for Black Creek coho, the single wild indicator on the Strait of Georgia for which there is a forecast, and for Robertson Creek, the single west coast Vancouver Island Vancouver Island indicator, are expected to be lower than in recent years. The forecast of lower survival for west coast Vancouver Island is reinforced by the lower forecast survival rate of 0.015 given by a biologically based model.

indicator	model	$\hat{s}_{1999}$	(50% CI)	change relative to 1998
Big Qualicum	LLY	0.003	(0.0013–0.008)	same
Quinsam	LLY	0.021	(0.013–0.034)	same
Chilliwack	RAT3	0.017	(0.010–0.027)	lower
Inch Creek	LLY	0.005	(0.003–0.010)	same
Black Creek	3YRA	0.042	(0.031–0.056)	lower
Robertson Creek	sibling regression	0.029	(0.020–0.041)	lower

7.2 Abundance forecast

Without fisheries information, forecasting abundance is highly problematic, and because we are using time-series models the forecast is dependent on the highly uncertain estimate of abundance in 1998. With those caveats the RAT3 forecast of the StG-Fr aggregate is 2.0×10^5 (50% CI: 1.5×10^5–2.8×10^5). This forecast portends a very worrisome further deterioration in the status of Strait of Georgia wild coho.

The LLY forecast for the wVI aggregate is 4.5×10^5 (50% CI: 3.1×10^5–6.5×10^5). This forecast is 77% of the overall average abundance of 5.9×10^5.

The abundance forecast for Thompson coho is for continued severe depression. Brood year escapements in the Thompson were very low and there is no indication that marine survival will improve either in the southern Strait of Georgia or on the west coast of Vancouver Island. We conclude that it is unlikely that stock size will increase appreciably for either the North or South Thompson aggregate in 1999.

7.3 Distribution forecast

The predicted proportion of catch inside the Strait of Georgia (p_{inside}) should there be no fishing restrictions is 0.33 (50%CI 0.25–0.42), which can be characterized as a moderately strong outside distribution. The confidence interval suggests that an extreme outside year ($p_{inside} < 0.2$) is about as likely as a return to a “normal” distribution ($p_{inside}>0.4$). Qualitative information (e.g. research trawl catches and observations by sport fishermen) suggests a strong outside distribution comparable to those observed in the past few years.

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Table 1. Release and recovery summaries for the six indicator streams used to generate forecasts.

brood year	number of coded-wire tagged smolts	estimated return age 3	estimated return age 2 (jacks)	marine survival age 3
Big Qualicum				
1972	112427	40122	1398	0.357
1973	57425	16546	931	0.288
1974	75512	12368	1482	0.164
1975	210520	28019	5860	0.133
1976	150348	28420	1504	0.189
1977	101224	21430	621	0.212
1978	107328	12181	543	0.113
1979	55435	5705	733	0.103
1980	51984	5791	271	0.111
2981	49274	3882	643	0.079
1982	42453	2127	181	0.050
1983	191620	1207	184	0.006
1984	152273	598	71	0.004
1985	119424	1393	440	0.012
1986	77760	1079	257	0.014
1987	102747	3776	739	0.037
1988	64833	3259	277	0.050
1989	36474	2134	187	0.059
1990	37362	2492	363	0.067
1991	38235	2618	188	0.068
1992	37957	1129	48	0.030
1993	38917	6198	237	0.016
1994	37616	525	87	0.014
1995	38827	124	41	0.003
Chilliwack				
1980	54665	6544	891	0.120
1981	28502	4097	626	0.144
1982	100841	18866	771	0.187
1983	72194	7172	198	0.099
1984	129770	21880	555	0.169
1985	59935	10863	845	0.181
1986	68658	8646	350	0.126
1987	39250	4164	271	0.106
1988	39801	3604	233	0.091
1989	395	2239	151	0.057
1990	39797	2361	152	0.059
1991	79613	3598	134	0.045
1992	39654	1481	153	0.037
1993	39808	1577	207	0.040
1994	36256	870	75	0.024
1995	74456	1563	117	0.021
Inch Creek				
1983	38711	2560	26	0.066
1984	38774	3440	197	0.089
1985	19723	4007	148	0.203
1986	19504	2116	22	0.108
1987	27458	2206	127	0.080
1988	38019	2690	36	0.071

brood year	number of coded-wire tagged smolts	estimated return age 3	estimated return age 2 (jacks)	marine survival age 3
1989	29367	2851	37	0.097
1990	31629	2607	91	0.082
1991	21172	1279	112	0.060
1992	20303	1116	10	0.055
1993	21540	834	90	0.039
1994	21174	226	5	0.011
1995	38707	201	12	0.005
Quinsam				
1975	73442	7129	2204	0.097
1976	139968	9303	3242	0.066
1977	168286	16778	2177	0.100
1978	226186	12602	2311	0.056
1979	280127	13387	3117	0.048
1980	76237	4973	501	0.065
1981	279799	15019	1343	0.054
1982	317306	27648	3443	0.087
1983	220929	17963	1530	0.081
1984	77380	6135	968	0.079
1985	42176	3352	924	0.079
1986	192294	14824	2765	0.077
1987	39362	3067	791	0.078
1988	39466	1650	299	0.042
1989	394	2317	251	0.059
1990	39411	1365	233	0.035
1991	42470	966	315	0.023
1992	43742	1098	353	0.025
1993	38947	377	129	0.010
1994	80125	953	128	0.012
1995	38827	831	643	0.021
Black Creek (wild indicator)				
1983	24134	3012		0.125
1984	31648	3602		0.114
1985	35640	4510		0.127
1986	74997	8500		0.113
1987	29203	3618		0.124
1988	118382	9004		0.076
1989	52351	6319		0.121
1990	49860	3161		0.063
1991	54996	3131		0.057
1992	75970	3416		0.045
1993	18152	611		0.034
1994	13736	599		0.044
1995	69996	3346		0.048
Robertson Creek				
1972	44536	2954	1624	0.066
1973	44071	3411	1234	0.077
1974	55672	4007	1054	0.072
1975	51460	2507	1628	0.049
1976	43047	3776	486	0.088
1977	51019	2369	433	0.046
1978	51916	1167	307	0.022

brood year	number of coded-wire tagged smolts	estimated return		marine survival age 3
		age 3	age 2 (jacks)	
1979	48776	974	110	0.020
1980	144742	8195	1038	0.057
1981	125895	8661	1056	0.069
1982	94740	1932	44	0.020
1983	52092	2038	85	0.039
1984	46061	1335	54	0.029
1985	41474	764	86	0.018
1986	50967	2514	412	0.049
1987	61191	5525	615	0.090
1988	43524	2569	139	0.059
1989	41773	1926	57	0.046
1990	40221	964	140	0.024
1991	38419	19	0	<0.0005
1992	36873	490	2	0.013
1993	42248	678	23	0.016
1994	43005	1312	228	0.031
1995	39566	1497	54	0.038

Table 2. Retrospective performance statistics for predictors of $\hat{s}_{smolt}$. Within each hatchery indicator the methods were compared over the same set of years. In the top section of the Table the number of observations in the comparison was determined by the requirement that the sibling regression data-set held at least nine observations. If in that comparison a time-series model outperformed the sibling regression then the comparison was restricted to the time-series models. These comparisons are shown in the bottom section of the Table. The 'best' model for each hatchery indicator is shaded**.**

predictor	Big Qualicum	Chilliwack	Quinsam	Inch Creek	Black Creek (wild)	Robertson Creek
	RMSE *MAD*					
N	15	7	12	5	no data	15
sibling regression	0.0532 0.0341	0.0362 0.0312	0.0432 0.0305	0.0641 0.0594		0.0193 0.0154
LLY	0.0208 0.0157	0.0156 0.0115	0.0148 0.0102	0.0173 0.0139		0.0236 0.0200
3YRA	0.0315 0.0269	0.0247 0.0210	0.0154 0.0116	0.0262 0.0244		0.0274 0.0227
RAT1	0.0189 0.0142	0.0160 0.0138	0.0214 0.0147	0.0143 0.0109		0.0382 0.0298
RAT3	0.0173 0.0133	0.0102 0.0087	0.0151 0.0109	0.0162 0.0151		0.0299 0.0228
N	20	12	17	10	9	20
LLY	0.0317 0.0216	0.0294 0.0210	0.0158 0.0116	0.0259 0.0201	0.0302 0.0224	0.0261 0.0222
3YRA	0.0361 0.0304	0.0305 0.0270	0.0165 0.0124	0.0275 0.0234	0.0264 0.0216	0.0275 0.0238
RAT1	0.0406 0.0267	0.0489 0.0325	0.0260 0.0201	0.0481 0.0289	0.0514 0.0360	0.0418 0.0324
RAT3	0.0453 0.0279	0.0294 0.0192	0.0170 0.0127	0.0405 0.0283	0.0337 0.0254	0.0318 0.0259

Table 3. Forecast of age 3 return ($\hat{R}_3^{1999}$) and survival ($\hat{s}_{smolt}$) for 1996 brood year for the four Strait of Georgia indicators and Robertson Creek using sibling regressions. Data used are found in **Table 1**. The slope and intercept are for the sibling regression model (Equation 6).

	Big Qualicum	Chilliwack	Quinsam	Inch Creek	Robertson Creek§
a (intercept)	1.743	2.840	1.361	5.260	5.553
b (slope)	1.084	0.979	1.039	0.549	0.387
N	24	16	21	13	22
$r^2_{adj.}$	0.74	0.63	0.79	0.41	0.51
R_2^{1998}	143	43	90	7	46
smolts released	*40331*	37282	39813	41918	39578
$\hat{R}_3^{1999}$	***1237***	***680***	***418***	***560***	***1136***
$\hat{s}_{smolt}$	***0.031***	***0.018***	***0.011***	***0.013***	***0.029***
CI:1% lower ‡	0.004	0.003	0.005	0.001	0.008
CI:5% lower	0.008	0.005	0.006	0.003	0.012
CI:10% lower	0.011	0.007	0.007	0.004	0.014
CI:25% lower	0.018	0.011	0.008	0.008	0.020
CI:75% lower	0.052	0.029	0.013	0.024	0.041

§: 1992 brood year was excluded

‡: In this case 1% of the observed values are expected to be less than the stated value.

Table 4. Forecasts of age 3 survival ($\hat{s}_{smolt}$) with confidence levels for the 1996 brood year, for the four Strait of Georgia hatchery indicators and one wild indicator and the wVI hatchery indicator. The predictions of the best performing models are shaded.

		Strait of Georgia indicator					wVI indicator
		Quinsam River	Big Qualicum River	Chilliwack River	Inch Creek	Black Creek (wild)	Robertson Creek
LLY	CI:75%	0.0340	0.0079	0.0337	0.0101	0.0673	0.0847
	$\hat{s}_{smolt}$	**0.0214**	**0.0032**	0.0210	**0.0052**	0.0478	0.0378
	CI:25%	0.0134	0.0013	0.0130	0.0027	0.0338	0.0164
	CI:10%	0.0087	0.0006	0.0082	0.0014	0.0241	0.0076
	CI:5%	0.0066	0.0003	0.0061	0.0010	0.0193	0.0046
	CI:1%	0.0038	0.0001	0.0033	0.0004	0.0119	0.0017
3YRA	CI:75%	0.0199	0.0190	0.0415	0.0146	0.0563	0.0448
	$\hat{s}_{smolt}$	0.0137	0.0090	0.0272	0.0102	**0.0415**	0.0263
	CI:25%	0.0094	0.0042	0.0178	0.0072	0.0305	0.0153
	CI:10%	0.0066	0.0021	0.0117	0.0051	0.0225	0.0092
	CI:5%	0.0053	0.0013	0.0089	0.0041	0.0184	0.0067
	CI:1%	0.0033	0.0005	0.0048	0.0025	0.0116	0.0035
RAT1	CI:75%	0.0616	0.0014	0.0339	0.0088	0.0838	0.2424
	$\hat{s}_{smolt}$	0.0351	0.0004	0.0183	0.0045	0.0518	0.0468
	CI:25%	0.0198	0.0001	0.0098	0.0023	0.0316	0.0075
	CI:10%	0.0116	0.0000	0.0054	0.0012	0.0195	0.0013
	CI:5%	0.0082	0.0000	0.0037	0.0008	0.0142	0.0004
	CI:1%	0.0040	0.0000	0.0017	0.0003	0.0071	0.0001
RAT3	CI:75%	0.0325	0.0033	0.0273	0.0033	0.0732	0.1640
	$\hat{s}_{smolt}$	0.0193	0.0011	0.0168	0.0019	0.0484	0.0501
	CI:25%	0.0114	0.0004	0.0103	0.0010	0.0317	0.0140
	CI:10%	0.0070	0.0001	0.0064	0.0006	0.0213	0.0042
	CI:5%	0.0051	0.0001	0.0046	0.0004	0.0165	0.0020
	CI:1%	0.0026	0.0000	0.0023	0.0002	0.0098	0.0004

Table 5. Data used for the biologically based survival forecast for Robertson Creek coho. The euphausiid biomass is the average June to October biomass of *Thysanoessa spinifera* in Barkley Sound in the smolt year (BY+2). The marine survival data are from Table 1.

return year (BY+3)	euphausiid biomass (mg dry mass/m^2)	Robertson Creek marine survival
1992	183	0.046
1993	127	0.024
1994	40	0.0048
1995	42	0.013
1996	42	0.016
1997	291	0.031
1998	76	0.036
1999	32	

Table 6. Data used in forecasting catch distribution of Strait of Georgia coho salmon. The salinity time series is the average sea-surface salinity measured at Sisters Island and Chrome Island lighthouses in February of BY+3.

Brood year	proportion of catch in the Strait of Georgia					February salinity (‰)
	Big Qualicum	Quinsam	Chilliwack	Inch Creek	Average (P_{inside})	
1972	0.6564				0.6564	29.55
1973	0.4518				0.4518	28.75
1974	0.5034				0.5034	29.30
1975	0.5171	0.5266			0.5218	28.54
1976	0.7854	0.5687			0.6771	29.50
1977	0.6204	0.4266			0.5235	28.75
1978	0.4134	0.2504			0.3319	27.65
1979	0.4358	0.3172			0.3765	28.34
1980	0.3637	0.2756	0.3667	0.4071	0.3533	28.04
1981	0.3449	0.3835	0.3802	0.4591	0.3919	28.25
1982	0.5699	0.5865	0.6432	0.7445	0.6361	29.20
1983	0.4686	0.4480	0.4785	0.6519	0.5118	29.10
1984	0.5669	0.6916	0.5492	0.7226	0.6325	28.95
1985	0.6751	0.5578	0.7338	0.8053	0.6930	29.75
1986	0.5269	0.4985	0.3711	0.6255	0.5055	28.95
1987	0.5910	0.6524	0.4974	0.6084	0.5873	29.05
1988	0.0938	0.1081	0.0290	0.2027	0.1084	27.00
1989	0.5717	0.5978	0.4896	0.5760	0.5588	27.40
1990	0.8265	0.8055	0.6726	0.8714	0.7940	29.34
1991	0.3603	0.4698	0.1759	0.4057	0.3529	28.75
1992	0.0215	0.0917	0.0021	0.1775	0.0732	27.70
1993	0.0439	0.1594	0.0327	0.1289	0.0912	26.90
1994	0.1010	0.0710	0.0001	0.4610	0.1583	27.14

Table 7. Correlations between p_{inside} for the four hatchery stocks on the Strait of Georgia. $N = 15$ for all correlations.

	Inch Creek	Big Qualicum	Chilliwack
Big Qualicum	0.934	1.000	
Chilliwack	0.914	0.950	1.000
Quinsam	0.864	0.958	0.889

Table 8. Forecast of p_{inside} for 1999 for Strait of Georgia hatchery indicators using the salinity model. Data used are in.

	overall (p_{inside})
$a^{\dagger}$	–28.9
b	1.002
N	23
$\hat{p}_{inside}$	*0.329*
CI:1% lower‡	0.100
CI:5% lower	0.151
CI:10% lower	0.184
CI:25% lower	0.246
CI:75% lower	0.424

†: The fitted model was $Logit(p_{inside}) = bS + a$ where *S* is the average February surface salinity at Chrome Island and the Sisters in BY+3.
‡: In this case 1% of the observed values are expected to be less than the stated value.

Table 9. Total stock size (N_h) for the four inside hatchery indicators and their proportions (p) of N_A, , the StG-Fr aggregate of wild stocks. Total stock size is the expanded recoveries of age 3 fish as recorded in MRP plus estimates of terminal FW harvest.

		Big Qualicum		Quinsam		Inch		Chilliwack		all combined	
return year	N_A	N	p	N	p	N	p	N	p	N	p
1984	2415519	92117	0.038	49579	0.021	656	0.000	26545	0.011	168897	0.070
1985	1542008	62904	0.041	98521	0.064	14282	0.009	83161	0.054	258868	0.168
1986	2019138	35599	0.018	131623	0.065	13392	0.007	210735	0.104	391349	0.194
1987	1801199	19818	0.011	98329	0.055	24890	0.014	314431	0.175	457468	0.254
1988	2376256	24361	0.010	102257	0.043	48526	0.020	326694	0.137	501838	0.211
1989	1288356	15000	0.012	137412	0.107	12688	0.010	211979	0.165	377079	0.293
1990	2053328	38486	0.019	82410	0.040	8629	0.004	184251	0.090	313776	0.153
1991	1555158	66694	0.043	48992	0.032	18719	0.012	165546	0.106	299951	0.193
1992	1974723	62121	0.031	69180	0.035	17135	0.009	108570	0.055	257006	0.130
1993	1881718	76190	0.040	42295	0.022	18736	0.010	113798	0.060	251019	0.133
1994	1393793	80011	0.057	27694	0.020	24275	0.017	130166	0.093	262146	0.188
1995	1287089	34047	0.026	28231	0.022	17396	0.014	73158	0.057	152832	0.119
1996	797267	21191	0.027	11552	0.014	17865	0.022	71288	0.089	121896	0.153
1997	363607	18198	0.050	13830	0.038	3036	0.008	42161	0.116	77225	0.212
1998		1913		12318		3912		32026		44558	

Table 10. Estimates of $\hat{N}_A$ for the StG-Fr aggregate.

	whole period		recent years (1990–1997)	
hatchery	p	$\hat{N}_A$	p	$\hat{N}_A$
Big Qualicum	0.0394	48609	0.0368	52051
Quinsam	0.0428	287567	0.0279	440943
Chilliwack	0.0648	493960	0.0460	696196
Inch Creek	0.0120	341962	0.0121	341157
average $\hat{N}_A$		288972		382587
overall	0.185	272762	0.160	314513

Table 11. Total stock size (N_h) for the single outside hatchery indicators and its proportion (p) of N_A, the wVI aggregate of wild stocks.

return year	N_A	N_h	p
1984	660059	61352	0.0929
1985	–†	25958	–
1986	608314	64290	0.1057
1987	1295715	42344	0.0327
1988	616236	21297	0.0346
1989	601214	56441	0.0939
1990	977262	48960	0.0501
1991	548391	69217	0.1262
1992	504734	71415	0.1415
1993	320019	33022	0.1032
1994	456507	373	0.0008
1995	501723	9742	0.0194
1996	382846	14397	0.0376
1997	176225	3953	0.0224
1998	450730	32310	0.0715

† The estimation procedure for N_w could not estimate stock composition in 1985.

Table 12. Forecasts of abundance for StG-Fr and wVI aggregates in 1999 ($\hat{A}_{1999}$), with retrospective analysis and confidence limits. The recommended models are shaded.

	StG-Fr aggregate abundance (×10^5)				wVI aggregate abundance (×10^5)			
	LLY	3YRA	RAT1	RAT3	LLY	3YRA	RAT1	RAT3
$\hat{A}_{1999}$	3.1	4.5	2.7	2.0	4.5	3.1	12	4.4
1%CI†	1.2	1.3	0.51	0.59	1.1	0.90	1.0	0.65
5%CI	1.6	2.0	0.91	0.92	1.7	1.4	2.5	1.3
10%CI	1.9	2.4	1.2	1.1	2.2	1.7	3.6	1.8
25%CI	2.4	3.3	1.8	1.5	3.1	2.3	6.6	2.8
75%CI	4.1	6.1	4.2	2.8	6.5	4.3	23	7.1
MAD (×10^5) 1988 to present	4.6	4.6	7.7	5.4	2.3	1.7	4.9	2.7
1993 to present	2.8	4.6	3.3	2.6	1.6	1.5	2.0	1.9
RMSE (×10^5) 1988 to present	5.4	5.1	9.7	6.6	3.0	1.9	7.9	3.8
1993 to present	3.4	5.2	3.7	3.0	1.8	1.9	2.2	2.1

† stated % of observations will be less than tabulated value

Table 13. Coho escapement time series for the eight North Thompson index streams.

year	Barrierre River	Cook Creek	E. Barrierre River	Fennel Creek	N. Thompson River	Raft River	Reg Christie Creek	Tumtum Creek
1975	300	–	60	90	1500	500	–	6
1976	360	–	30	95	1500	250	50	–
1977	420	–	18	380	400	350	8	10
1978	400	60	110	300	300	250	20	10
1979	400	60	120	600	125	120	5	4
1980	60	10	25	40	100	90	10	4
1981	350	45	60	100	300	110	15	–
1982	450	50	75	450	90	200	15	2
1983	250	100	100	280	125	250	5	50
1984	500	–	250	700	700	960	25	25
1985	425	0	140	450	100	–	0	25
1986	–	65	250	1250	500	800	25	80
1987	500	200	100	580	500	400	0	0
1988	600	25	225	800	600	650	15	0
1989	175	70	160	60	680	170	22	25
1990	–	100	–	200	774	50	200	26
1991	0	10	0	–	667	200	24	0
1992	100	20	0	–	740	100	70	45
1993	100	4	50	–	350	50	1	12
1994	–	0	0	50	358	301	0	2
1995	85	0	50	0	150	40	0	2
1996	–	0	10	–	92	15	20	0
1997	0	0	–	0	200	–	30	40
1998	85	0	47	75	101	144	75	14

Table 14. Coho escapement time series for eight index streams in the South Thompson River drainage from 1975 to 1998.

year	Adams River	Bessette System	Blurton Creek	Bolean Creek	Canoe Creek	Hunakwa Creek	Kingfisher Creek	Scotch Creek
1975	200	1220	–	–	25	25	25	25
1976	10	495	25	50	10	25	10	5
1977	338	166	40	0	0	0	62	0
1978	150	580	10	50	100	200	10	0
1979	100	530	25	50	10	75	25	0
1980	200	490	16	20	60	42	0	–
1981	100	345	15	55	30	25	25	–
1982	100	320	0	100	80	50	100	20
1983	100	610	0	50	20	50	75	25
1984	650	1000	50	10	30	125	25	–
1985	500	1350	50	100	100	0	25	0
1986	150	1120	50	50	30	0	80	50
1987	150	950	50	0	100	0	120	50
1988	500	1300	70	50	75	150	150	100
1989	350	1190	35	35	100	120	50	50
1990	100	475	50	35	50	30	0	50
1991	100	50	0	0	30	75	0	40
1992	250	950	50	0	20	120	45	50
1993	20	144	30	–	25	–	60	10
1994	70	284	8	0	6	90	32	10
1995	75	475	0	20	10	60	25	20
1996	16	62	0	0	0	2	0	16
1997	40	43	0	–	10	20	50	2
1998	116	101	0	0	0	48	29	0

Table 15. Coho escapement time series for eight additional index streams in the South Thompson River drainage from 1975 to 1998.

year	Shuswap River (lower)	Shuswap River (mid)	South Pass Creek	Tappen Creek	Trinity Creek	Wap Creek	Upper Adams River	Sinmax Creek
1975	100	150	–	–	21	150	60	60
1976	40	60	20	1	8	20	50	18
1977	100	594	40	12	21	516	150	40
1978	300	350	50	2	4	300	100	55
1979	300	500	60	3	45	400	475	140
1980	350	550	20	0	10	250	75	–
1981	250	250	20	15	10	100	100	–
1982	300	350	50	5	35	225	200	15
1983	200	250	10	0	10	80	300	10
1984	300	700	25	20	30	150	200	–
1985	500	1200	50	30	20	250	500	75
1986	600	650	50	30	60	200	1100	80
1987	350	500	53	30	20	450	500	120
1988	400	1200	75	40	50	250	700	80
1989	250	500	50	35	50	250	1100	40
1990	200	200	50	15	50	200	220	0
1991	200	300	25	0	10	75	100	0
1992	250	800	85	15	50	300	0	0
1993	20	20	7	–	6	–	60	8
1994	100	300	2	0	13	180	159	0
1995	25	50	25	10	0	50	126	17
1996	0	120	0	0	8	33	120	7
1997	0	200	2	–	0	35	105	9
1998	0	115	3	20	0	93	230	4

Table 16. Exploitation rate, escapement and total return for North and South Thompson average-streams. The marine survival and exploitation rates are averages of the Thompson indicator streams.

			South Thompson		North Thompson	
year	marine survival rate	exploitation rate	escapement	total return	escapement	total return
1975		0.664	124	370	253	752
1976		0.664	58	174	242	721
1977		0.664	121	359	169	502
1978		0.664	150	446	184	547
1979		0.664	169	503	174	518
1980		0.664	111	330	43	127
1981		0.664	104	311	136	407
1982		0.664	154	460	160	475
1983		0.664	92	273	200	594
1984		0.664	183	543	387	1151
1985		0.664	243	723	181	538
1986		0.664	238	710	416	1237
1987	0.036	0.534	221	475	272	583
1988	0.046	0.719	323	1150	301	1071
1989	0.076	0.653	242	698	188	541
1990	0.028	0.739	146	558	268	1027
1991	0.0037	0.673	64	197	74	227
1992	0.019	0.818	184	1009	160	879
1993	0.0028	0.88	66	548	74	620
1994	0.011	0.434	59	104	56	98
1995	0.024	0.566	62	144	40	92
1996	0.037	0.764	17	72	23	97
1997	0.012	0.352	29	45	82	127
1998		0.107	44	49	91	102

Table 17. Forecasts of average-stream total returns to the North and South Thompson for 1999 with their associated confidence intervals. Both forecasts were based on the 3YRA model.

	North Thompson		South Thompson	
CI	total return	% of average total return	total return	% of average total return
99%	724	133	437	102
95%	395	73	252	59
90%	293	54	192	45
75%	181	33	124	29
50%	**108**	**20**	**77**	**18**
25%	64	12	48	11
10%	40	7	31	7
5%	30	5	24	6
1%	16	3	14	3

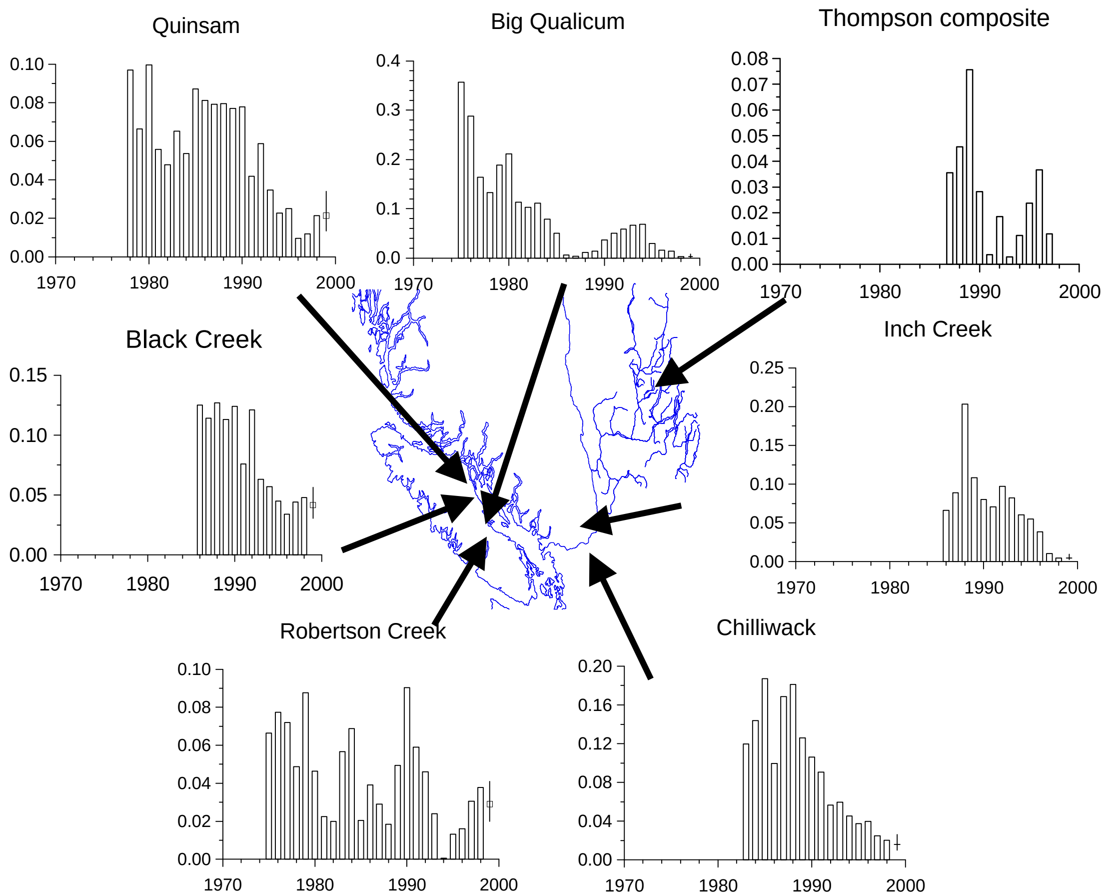


Figure 1. Marine survivals vs. return year for seven coho indicators in southern British Columbia. The forecast survivals for 1999 are shown with associated 50% CIs. The Thompson values are a composite of all available smolt release data. A 1999 forecast survival is not available for the Thompson.

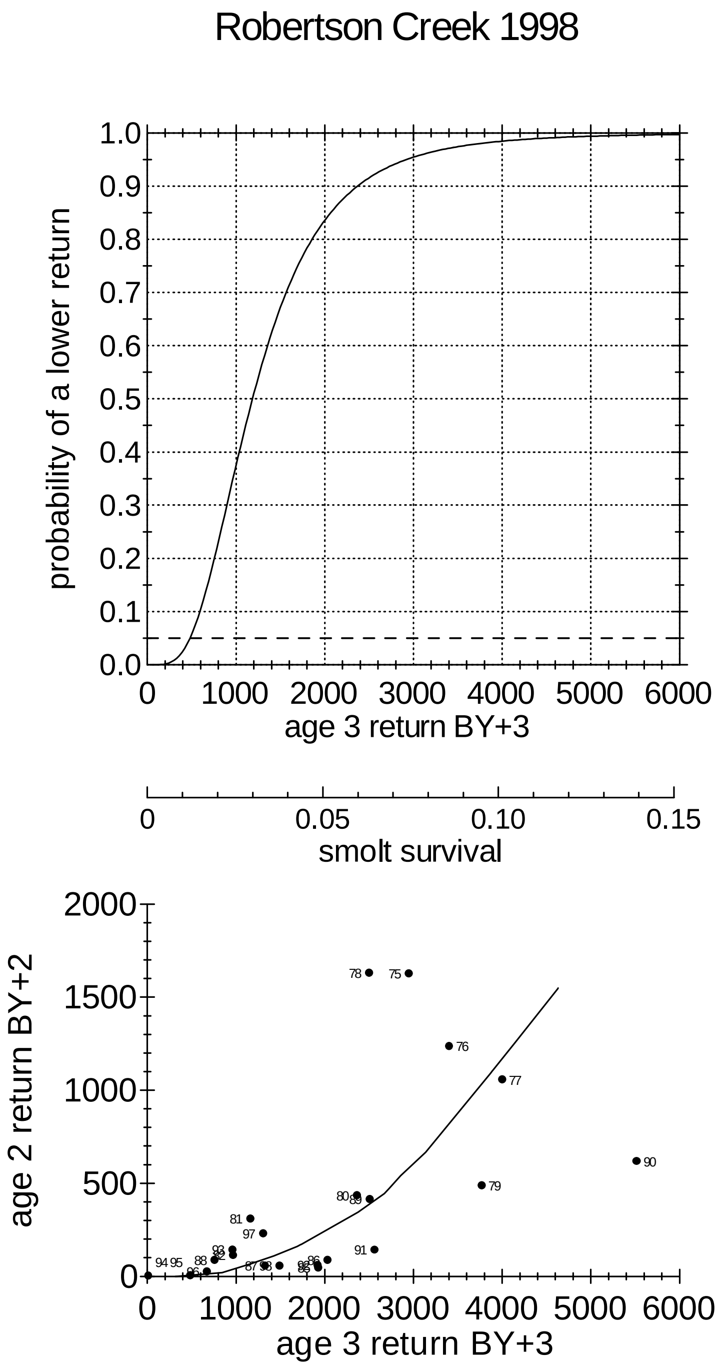


Figure 2. Return and survival forecast for Robertson Creek coho in 1999 using the sibling regression model. The lower panel is the sibling relationship. The upper panel is the probability distribution for the predicted age 3 return. Returns can be converted to survival using the middle scale.

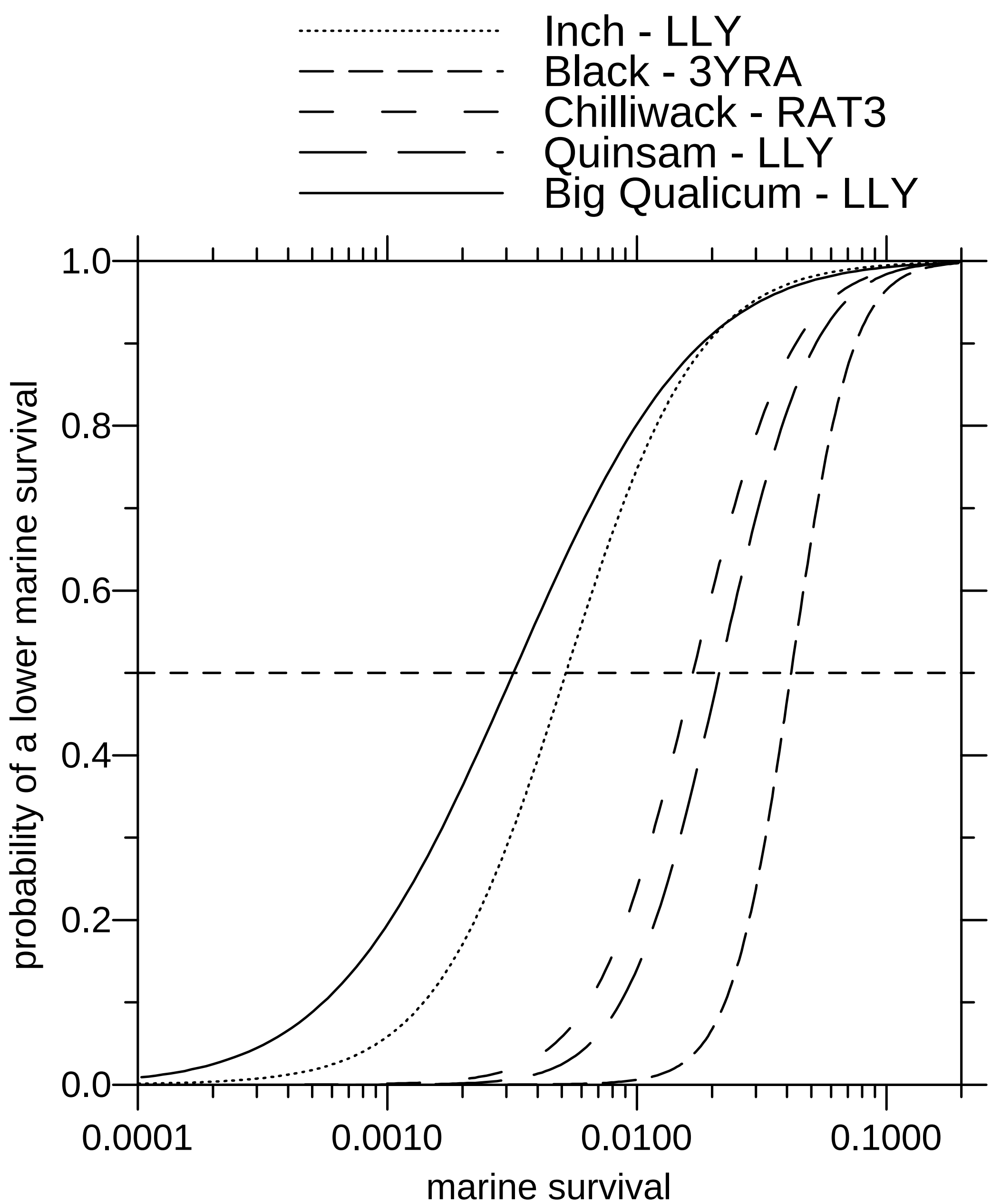


Figure 3. Confidence intervals around the time-series forecasts of marine survivals for four hatchery indicators and Black Creek.

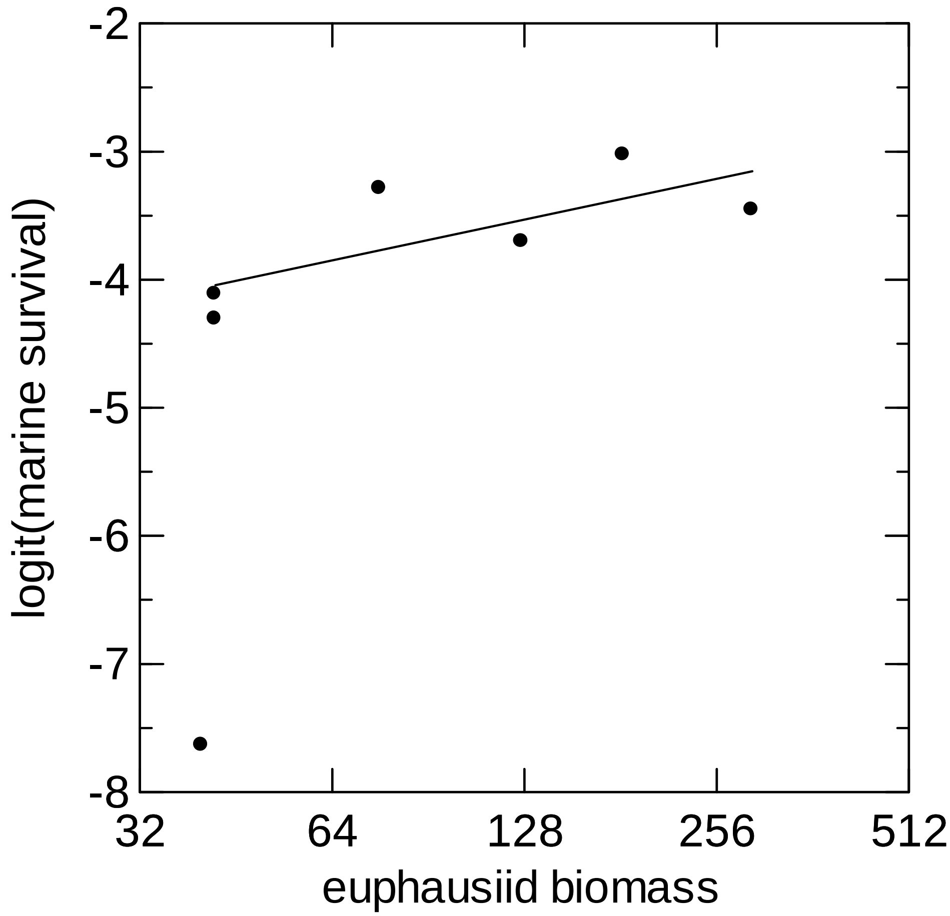


Figure 4. Marine survival at Robertson Creek vs. euphausiid biomass in Barkley Sound. The outlier (1994 return year) was excluded from the fitted line shown.

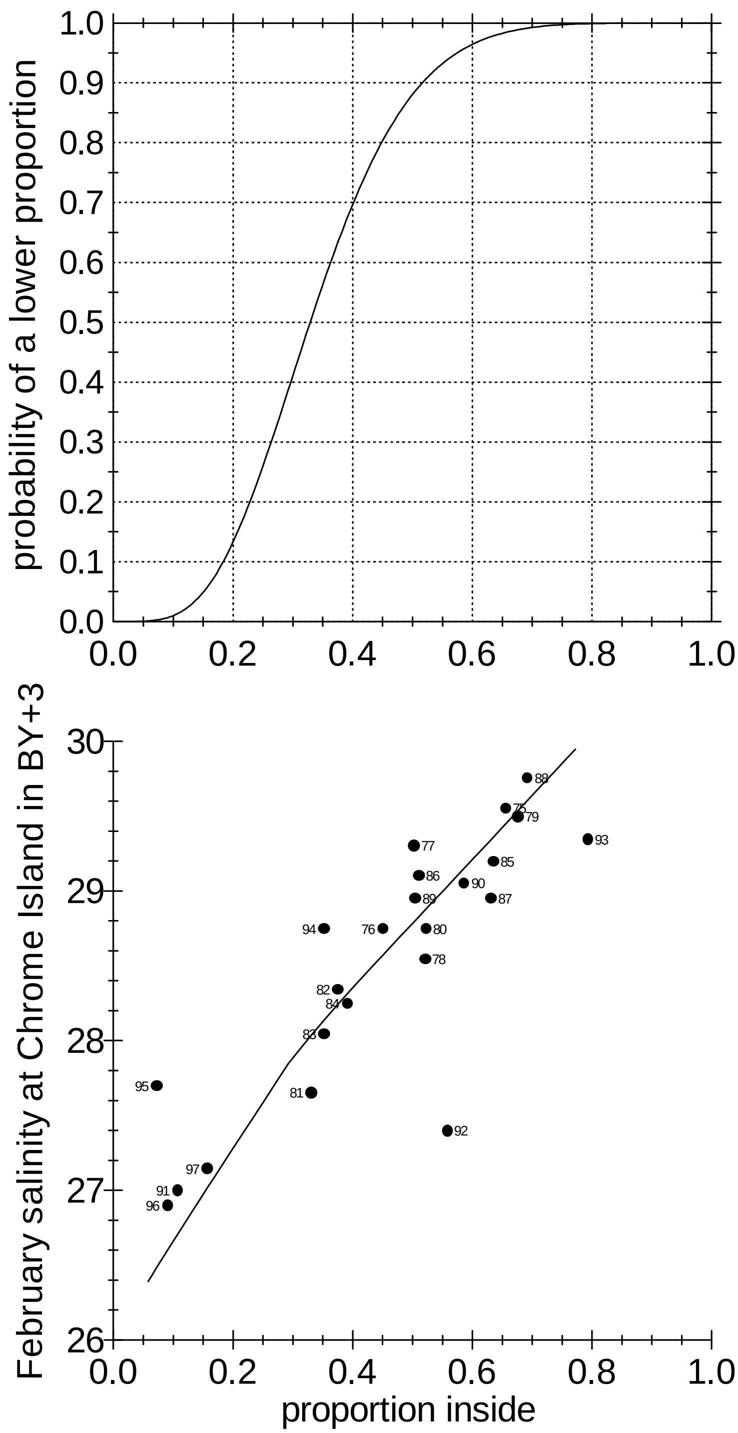


Figure 5. Predicting pinside for 1999 using average Chrome Island and the Sisters February salinities. The lower panel is the predictive relationship. The upper panel is the probability distribution for the point predictions. A February salinity of 28.07 was used.

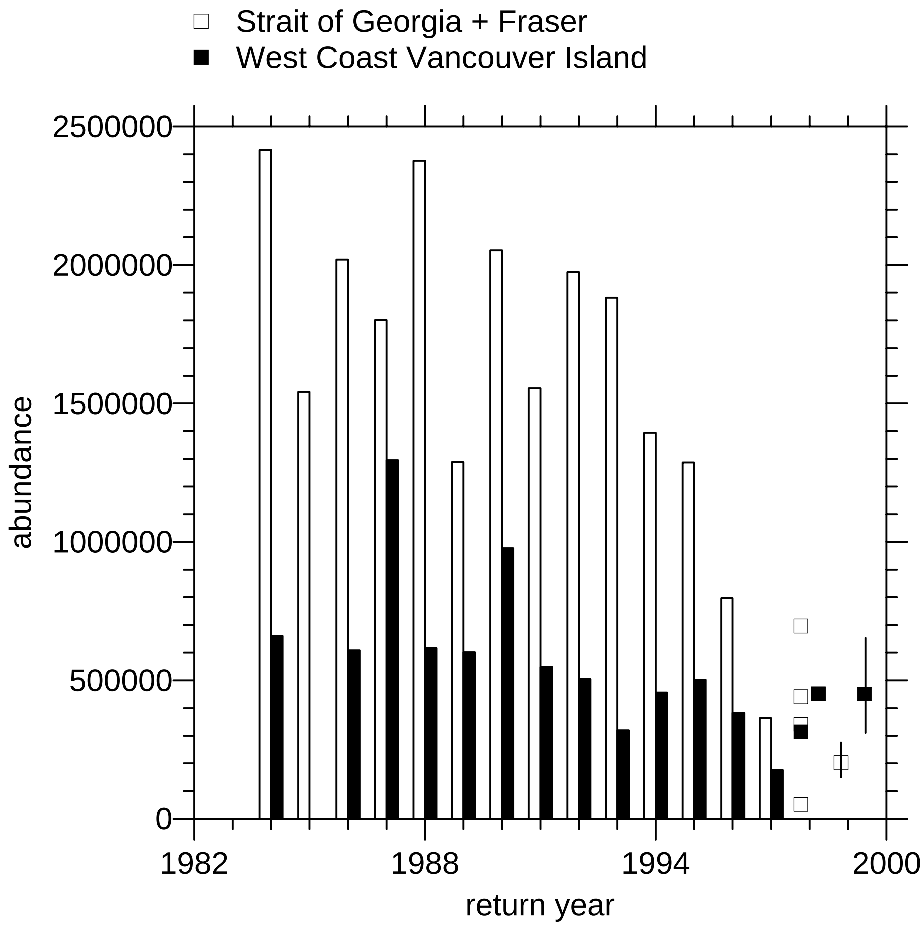


Figure 6. Abundance estimates for the Strait of Georgia+Fraser aggregate and the West Coast Vancouver Island aggregate of southern British Columbia coho. Values shown for 1998 are for estimates derived from each hatchery indicator and for all hatcheries combined (the overall p_h) for the period 1990 to 1997. For the StG-Fr aggregate the preferred estimate of 1998 abundance is shaded. The forecast abundances for 1999 with associated 50% CI are shown for both aggregates.

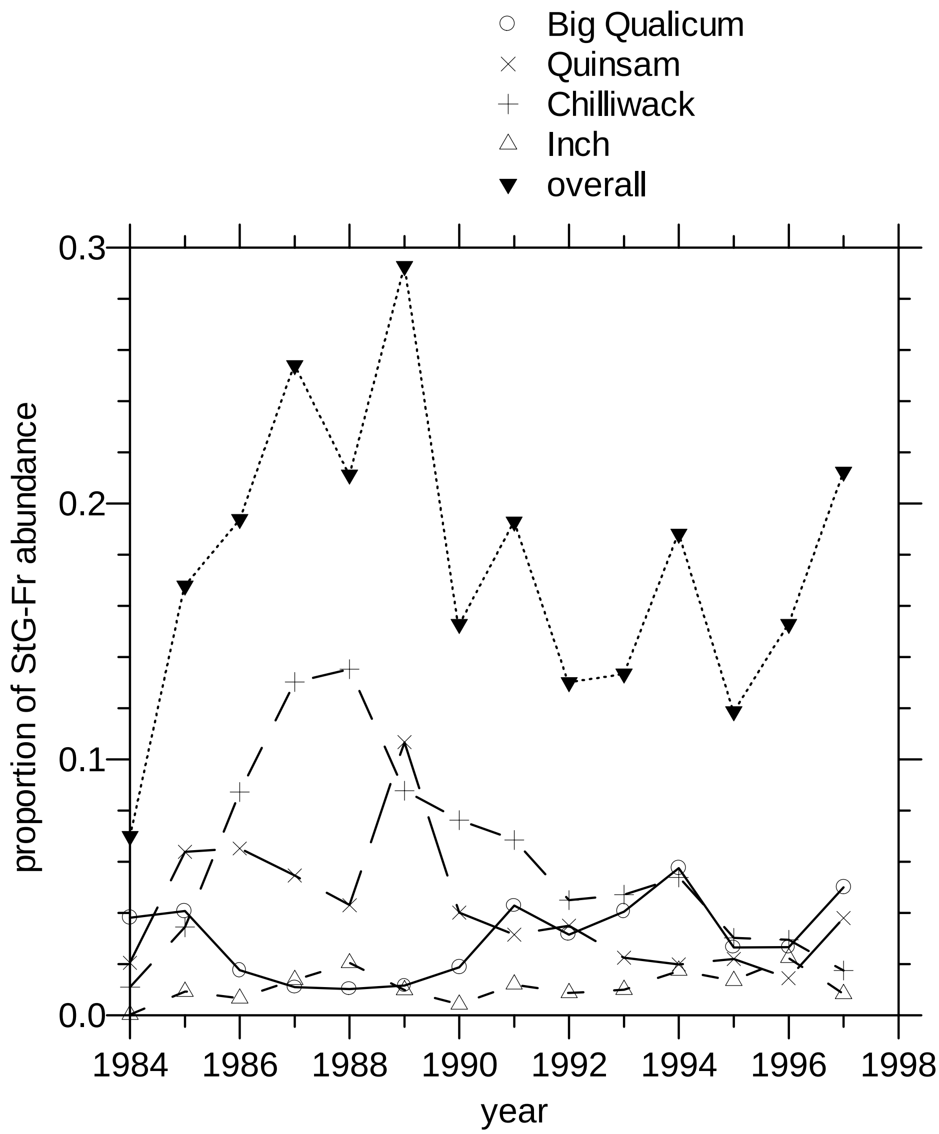
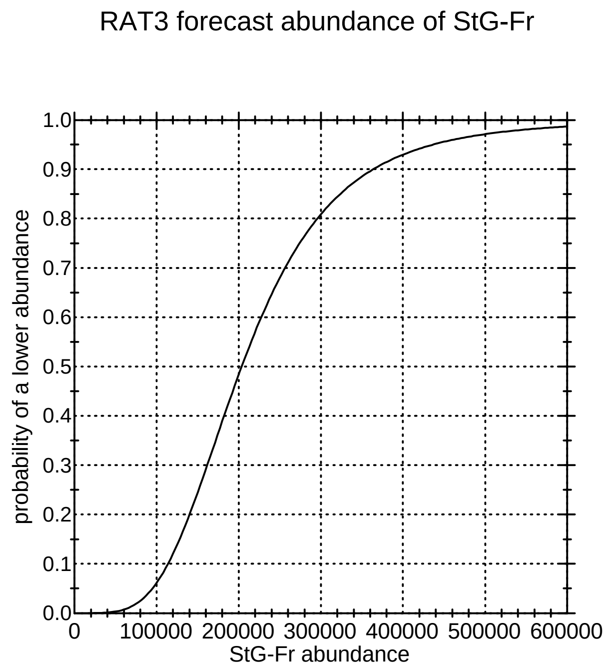


Figure 7. The ratio of the return to each hatchery to the estimated abundance of the StG-Fr aggregate. The overall proportion was calculated by summing the hatchery indicator abundances before calculating the ratio.



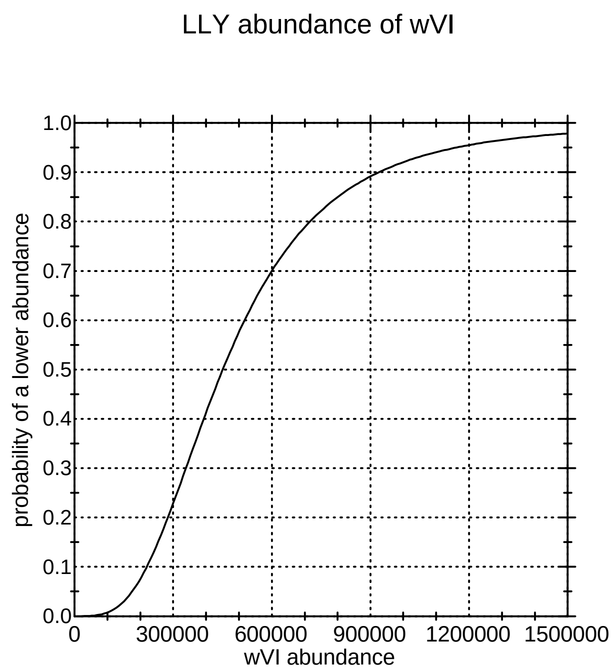


Figure 8. Probability plots for the abundance forecasts for StG-Fr and wVI aggregate abundance in 1999 using the recommended models.

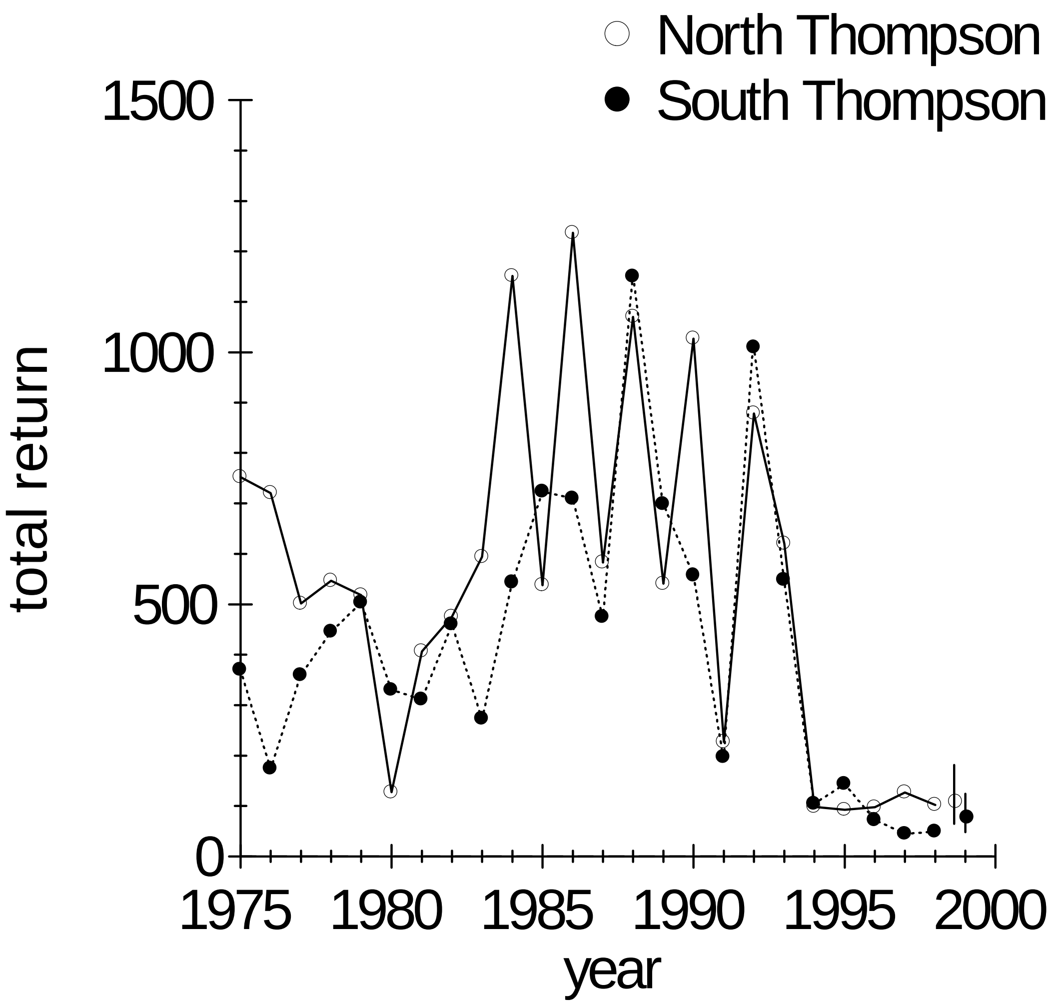


Figure 9. Total returns to North and South Thompson aggregates from 1975 to 1998. The forecasts for 1999 with their 50% CI are shown.