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Forecast for Southern British Columbia Coho Salmon in 2001

K. Simpson, D. Dobson, J. Irvine, B. Holtby, R.W. Tanasichuk

Fisheries and Oceans Canada
Stock Assessment Division, Science Branch
Pacific Biological Station
Nanaimo, B.C.
V9R 5K6

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Abstract

This Working Paper documents forecasts of marine survival, abundance and distribution for the coho salmon of southern British Columbia (Strait of Georgia, west Vancouver Island, lower Fraser and interior Fraser including the Thompson River) for return year 2001.

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[1]	Predicted Survival in 2001 (50% CI)	Change (2001 forecast minus 2000 observed S)
Big Qualicum	LLY	0.020 (0.012-0.031)	0.000
Quinsam	3YRA	0.011 (0.008-0.014)	-0.006
Chilliwack	RAT3	0.014 (0.011-0.019)	-0.009
Inch	3YRA	0.012 (0.006-0.023)	-0.002
Black Creek	3YRA	0.026 (0.021-0.033)	0.004
Robertson:	Sibling, RCH	0.039 (0.026-0.059)	-0.037
	Euphausiid,RCH	0.040 (0.021-0.063)	-0.036
Carnation Creek	Euphausiid, RCH	0.102 (0.066-0.143)	0.054

[1] LLY: Like last year; 3YRA: like mean of last 3 years; RAT3: same change as the mean of the last 3 interannual changes; RCH: using escapement counts at Robertson Creek Hatchery.

For populations around the Strait of Georgia, survivals are forecast to change very little. Survival will remain poor throughout southern BC and survival is forecast to improve only marginally at Black Creek. None of the sibling models performed better than the statistical models. However, all the regressions predict better survivals, particularly in the lower Fraser system, and marine data also suggest that the forecasts are more likely to be conservative than not.

Euphausiid and sibling survival forecasts are presented for Robertson Creek coho on the west coast of Vancouver Island (wVI). Bearing in mind that both badly under-forecast the 2000 survival of 7.6%, they predict a survival in 2001 that is similar to the mean 1990's survival and about half of last year's unusually large survival. Using an alternate estimate of Robertson escapements (see below) resulted in larger survivals in the time series, including a larger forecast. However, the 2001 forecast remains in the same proportion to last year and the 10 year average of the new time series. Carnation Creek has been added to the forecast this year. The forecast survival of 10.2% is a substantial increase over the 4.8% last year and is better than the 1990's average of 8.4%.

Abundance

Forecasting abundance is highly problematic, particularly in the present regime of low exploitation. The abundance in 2000 was estimated to be 560,000 for populations in the Georgia Basin, which is more than the upper 95% confidence limit for the forecasted abundance of 250,000. This year the best model is the LLY model, meaning that, like survivals, we are forecasting no change in abundance. This 2001 abundance forecast of 560,000 is 40% of the long term mean abundance of 1.4 million.

The estimated abundance of the wVI aggregate in 2000 (920,000) was extreme compared to the forecast (270,000; upper 99% confidence limit: 900,000). This was attributable to a very large escapement to the hatchery. Although there was also a large relative increase in the escapement to Carnation Creek, all our other escapement data indicated only a slight improvement in abundance. This stimulated us to examine the effect of using Stamp Falls counts as an alternate estimate of Robertson escapement, which we think were

underestimated before 2000 to an unknown degree. The abundance estimate for 2000 was slightly higher using this data (1.15 million). However, 1999 and many preceding years were higher yet so the difference from 1999 to 2000, although still large, was about half the difference using hatchery escapements. Escapement in 2000 to the Somass system, including Robertson, was obviously large compared to most other wVI areas. This occurrence highlights the vulnerability of wVI forecasts based on only one exploitation and survival rate indicator. The forecast of wVI abundance in 2001, based on the 3YRA forecast model of abundances, is for 460,000 (50% CI: 310,000 – 670,000). The 2000 estimate and 2001 forecast represent 175% and 84% of the long term mean abundances, respectively.

The forecast total abundance of Thompson River watershed coho in 2001 is ~17,500, similar to the estimated abundance in the brood year and only about 20% of the long term mean abundance. The overall abundance of Thompson coho has not increased significantly in recent years but spawner numbers are increasing. Escapements in 2000 and 1999 were both larger than brood year escapements. Greater proportions of fish surviving to maturity are returning to spawn because of 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 (p_{inside}) is 0.70 (50%CI: 0.60-0.78), which is a very strong inside distribution. There is less than a 1% chance of a moderate outside year occurring if that is defined as $p_{inside} < 0.3$. Some Georgia Basin stocks, including Thompson and Cowichan, have a greater propensity to rear outside even in inside years. Therefore, Thompson coho will probably occur in both areas in 2001, as they have in previous inside years.

Résumé

Le présent document de recherche porte sur les prévisions de la survie en mer, de l'abondance et de la répartition du saumon coho du sud de la Colombie-Britannique (détroit de Georgie, ouest de l'île de Vancouver, bas Fraser et bassin supérieur du Fraser (y compris la rivière Thompson) pour l'année de remonte 2001.

Survie en mer

Des recommandations relatives à la prévision de la survie en mer de cinq stocks d'élevage et de deux stocks sauvages de saumon coho servant d'indicateurs sont présentées dans le tableau suivant :

Stock indicateur	Modèle recommandé [1]	Survie prévue en 2001 (IC à 50 %)	Écart par rapport au taux de survie observé en 2000
Big Qualicum	LLY	0,020 (0,012-0,031)	0,000
Quinsam	3YRA	0,011 (0,008-0,014)	-0,006
Chilliwack	RAT3	0,014 (0,011-0,019)	-0,009
Inch	3YRA	0,012 (0,006-0,023)	-0,002
Black Creek	3YRA	0,026 (0,021-0,033)	0,004
Robertson	Espèces jumelles, RCH	0,039 (0,026-0,059)	-0,037
	Euphausiacés, RCH	0,040 (0,021-0,063)	-0,036
Carnation Creek	Euphausiacés, RCH	0,102 (0,066-0,143)	0,054

[1] LLY : Like last year (comme l'année dernière);
3YRA : like mean of last 3 years (comme la moyenne des trois dernières années);
RAT3 : same change as the mean of the last 3 interannual changes (même écart que la moyenne des trois derniers écarts interannuels);

RCH : using escapement counts at Robertson Creek Hatchery (selon l'échappée observée à l'écloserie du ruisseau Robertson).

On prévoit très peu de changement dans la survie des populations autour du détroit de Georgie. La survie restera faible dans l'ensemble du sud de la C.-B., et on ne prévoit qu'une légère amélioration de la survie dans le ruisseau Black. Aucun des modèles des espèces jumelles n'a mieux fonctionné que les modèles statistiques. Toutefois, toutes les régressions prévoient une meilleure survie, particulièrement dans le bassin inférieur du Fraser, et les données marines laissent aussi croire que les prévisions seront sans doute inférieures aux valeurs réelles.

Les prévisions de survie fondées sur les modèles des euphausiacés et des espèces jumelles sont présentées pour le coho du ruisseau Robertson, situé sur la côte ouest de l'île de Vancouver (wVI). Selon ces prévisions, la survie en 2001 devrait être semblable à la moyenne des années 1990, soit environ la moitié de la survie exceptionnellement forte de l'an dernier, mais il faut garder à l'esprit que les deux modèles ont de beaucoup sous-estimé la survie en 2000 qui a atteint 7,6 %. Si l'on utilise une autre estimation de l'échappée du ruisseau Robertson (voir plus bas), on obtient des survies plus fortes dans la série chronologique, y compris une prévision plus élevée. Toutefois, la prévision pour 2001 présente la même proportion par rapport à l'an dernier et à la moyenne sur dix de la nouvelle série chronologique. On a ajouté les données du ruisseau Carnation aux prévisions cette année. La survie prévue de 10,2 % constitue une hausse substantielle par rapport à l'année dernière (4,8 %) et dépasse la moyenne des années 1990, soit 8,4 %.

Abondance

Il est très difficile de prévoir la taille des stocks, particulièrement lorsque les niveaux d'exploitation sont bas, comme c'est le cas actuellement. En 2000, les effectifs des populations du bassin de Georgie ont été estimés à 560 000, ce qui dépasse la limite supérieure de confiance à 95 % de l'abondance prévue de

250 000. Cette année, le modèle LLY est celui qui fonctionne le mieux, ce qui signifie que nous ne prévoyons aucun changement de l'abondance, comme pour la survie. La prévision de l'abondance de 2001, soit 560 000 cohos, représente 40 % de l'abondance moyenne à long terme (1,4 million).

En 2000, la taille estimée du stock combiné de wVI (920 000) dépassait énormément la prévision (270 000; limite supérieure de confiance à 99 % = 900 000).   Cela est attribuable à une très grande échappée vers l'écloserie. L'échappée dans le ruisseau Carnation a aussi présenté une importante hausse relative, mais toutes les autres données d'échappée n'indiquent qu'une légère augmentation de l'abondance. Cela nous a incités à examiner l'effet de l'utilisation des dénombrements effectués aux chutes Stamp pour obtenir une autre estimation de l'échappée du ruisseau Robertson, que nous croyons avoir été sous-estimée dans une mesure inconnue avant 2000. L'estimation de l'abondance en 2000 à partir de ces données était légèrement plus élevée (1,15 million).   Toutefois, comme l'abondance en 1999 et pour de nombreuses années antérieures était encore plus élevée, l'écart toujours grand entre 2000 et 1999 représentait environ la moitié de celui calculé à l'aide des échappées vers l'écloserie. De toute évidence, l'échappée dans le bassin de la Somass, y compris le ruisseau Robertson, était grande par rapport à la plupart des autres secteurs de wVI. Cette constatation met en évidence le manque de fiabilité des prévisions pour la région wVI qui sont fondées sur les taux d'exploitation et de survie d'un seul stock indicateur. Selon le modèle 3YRA, la prévision de l'abondance de cohos dans la région wVI en 2001 est de 460 000 (IC à 50 % = 310 000 – 670 000). L'estimation pour l'an 2000 et la prévision pour 2001 représentent respectivement 175 % et 84 % de l'abondance moyenne à long terme.

L'abondance totale prévue des cohos dans le bassin de la Thompson en 2001 se chiffre à ~17 500, valeur semblable à l'abondance estimée pour l'année de génération et qui ne correspond qu'à environ 20 % de l'abondance moyenne à long terme. L'abondance globale des cohos de la Thompson n'a pas augmenté de façon marquée ces dernières années, mais le nombre de géniteurs est à la hausse. Les échappées de 2000 et de 1999 étaient plus fortes que les échappées des années de génération. D'importantes réductions de la pression de pêche permettent à une plus grande proportion des poissons qui arrivent à maturité de revenir frayer. Ainsi, si l'on suppose que la survie en mer et la pression de pêche restent faibles, l'état du coho de la Thompson et d'autres stocks du bassin supérieur du Fraser devrait s'améliorer lentement et graduellement.

Répartition

Dans l'hypothèse du maintien de la répartition historique de la pêche, la proportion prévue des prises dans le détroit de Georgie (p_{inside}) serait de 0,70 (IC à 50 % = 0,60-0,78), ce qui constitue une répartition très forte à l'intérieur du détroit. Une année de répartition modérée à l'extérieur du détroit (définie comme $p_{inside} < 0,3$) a moins de 1 % de chance de se produire.   Certains stocks du bassin de Georgie, notamment ceux de la Thompson et de la Cowichan, ont plus tendance que d'autres à être présents à l'extérieur du détroit, même lors d'années de répartition à l'intérieur. En 2001, les cohos de la Thompson se trouveront donc sans doute dans les deux régions, comme lors d'années antérieures de répartition à l'intérieur.

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1. Introduction

This Working Paper presents forecasts of the marine survival rate, the ocean distribution and the ocean abundance of southern British Columbia coho in 2001. The methods we used in developing the forecasts of marine survival rate and ocean distribution are similar to those used in previous working papers (Holtby et al. 1999, 2000; Holtby and Kadowaki 1998; Kadowaki 1997; Kadowaki et al. 1996). Due to time limitations, this report freely uses text and format from Holtby et al. (2000).

2. Data Sources and Treatments

2.1 Interior Fraser including the Thompson River

The interior Fraser is defined as the Fraser River watershed above Hell's 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 mainstem South Thompson River and tributaries upstream from the confluence of the North Thompson River;
2. North Thompson – the mainstem North Thompson River and its tributaries;
3. Lower Thompson – the mainstem Thompson and tributaries downstream from the confluence of the North and South Thompson, including the Nicola watershed; and
4. Fraser/non-Thompson – the Fraser River and tributaries upstream of the Fraser Canyon excluding the Thompson.[1]

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. Although spawner estimates for many systems exist going back to the 1950's, inconsistent and often undocumented effort make many of the original estimates unreliable. We have been able to reliably reconstruct the escapement time series for North and South Thompson streams 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, and some are still not.[2] 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 1).

The survey effort expended in many systems during 1998-2000 exceeded the effort given in previous years. During these three years, two separate escapement estimates were obtained for many systems. The first is our best estimate of the true number of coho in the system. The second is what we refer to as a trend estimate, which is the probable number of fish that would have been estimated if survey effort had been similar to other recent years. See Irvine et al. (1999b) for details on how these estimates were generated. For this forecast document, escapement estimates in all of the wild streams pre-1998 were adjusted upward to estimate actual escapements. The escapement time series since 1998 consists of our best estimates of the true numbers of coho spawning in each system. For streams where estimates of the adjustment scalar were available for both 1998 and 1999, the geometric mean of the scalar was applied to pre-1998 escapement estimates. For streams where only one estimate of the adjustment scalar was available or no estimate of the scalar was available, the geometric mean scalar for the aggregate over both years was applied to historical escapement estimates. A very large scalar for lower Shuswap River in 1998 was excluded from the

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[1] In the previous year's forecast document (Holtby et al. 2000), sub-regions 3 and 4 were combined in the analysis; here we keep them separate.
[2] 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 now an ongoing coho sampling program in the Fraser canyon using a fishwheel. DNA samples are taken at the fishwheel to identify stocks.

average. For enhanced systems with counting fences, we generally assumed the estimates were accurate. However, in 1996 for the Eagle River and 1997 for both the Eagle and Salmon rivers in the South Thompson, technical difficulties led to under-estimates of escapement in these two enhanced systems. Total 1996 and 1997 escapements to these systems were estimated using the approach applied to the time series of non-enhanced streams. Catch and abundance (i.e. catch + 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 2).

The time series of exploitation rates for the Thompson were taken from the Mark Recovery Program (MRP) recoveries for a variety of releases from 1986 to 1997 and revised escapement estimates. Estimates prior to 1986 were the arithmetic average of measured values from 1986 to 1996. Estimated exploitation in 1998 and 1999 was approximately 7% and 9%, as previously reported (Irvine et al. 2000). The estimated exploitation rate in 2000 is 3.4% but this value is preliminary.

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

Preliminary catch and escapement data were used for coded-wire tagged (CWT'd) coho from the Big Qualicum, Quinsam, Chilliwack, Inch and Robertson hatchery stocks and from the Black Creek wild indicator. Data sources were the MRP database maintained at the Pacific Biological Station in Nanaimo, BC; the Habitat and Enhancement Branch (pers. comm. S. Lehmann, HEB Vancouver); and the Stock Assessment Division (KS). Smolt releases since 1998 have included CWT-adipose clipped and CWT-only components. Freshwater sport recoveries of CWT'd coho were added to the escapement rather than treated as catch to better represent the exploitation rate on wild stocks, which were not exposed to intense terminal fisheries. Only externally marked fish were retained in these fisheries.

Survival rate estimates are based only on CWT-ad fish. Mortality that occurred outside of any retention fisheries on marked fish was ignored but it is thought to have been small. This follows the recent practice of not including release mortality estimates in survival calculations (e.g. Holtby et al. 2000; Simpson et al. 2000). Data for each indicator are shown in Table 3.

For abundance estimates, which rely on estimates of total return to hatcheries, an allowance for release mortality was included by assuming a 5% Canadian exploitation rate. Washington catch data are not available yet. Release mortalities and catches in Washington were estimated using the same figures used by Holtby et al. (2000): 0% for Robertson coho; 1% for Big Qualicum and Quinsam coho; 3% for Chilliwack coho; and 4% for Inch coho. Alaskan catches in 2000 are entered in the MRP database and were used.

We think it is reasonable to not include estimates of the fishing mortality of unmarked releases from the hatchery indicators when estimating total returns for the abundance estimates. The proportion of 1997 brood coho that were not marked at indicator hatcheries other than Quinsam was only 5.2% (range 4.6 – 5.9%)[3]. The sources of their mortality would be largely from Washington and Alaskan catch and from mortality of released fish in BC and Washington. The Alaskan catch of these stocks is small, release mortality at 10% of sport encounters would also be very small (as evidenced by the exploitation rates of marked coho), and Washington exploitation would not be large. Black Creek is a wild indicator stream and no fish from there were given an adipose clip. Holtby et al. (2000) assumed the number of unmarked coho from Black Creek that were encountered by sport fishermen was equal at least to number calculated using the exploitation of marked Quinsam coho groups. Black and Quinsam coho have shared the same catch distribution in the past (Simpson et al. 2000). Since virtually all Canadian exploitation was from sport fisheries, many of which were mark selective fisheries, they calculated a minimum fishing mortality of Black coho equal to the exploitation in Alaska plus 10% of the Canadian exploitation (10% being the assumed release mortality). Exploitation in WA fisheries of Black Creek coho is known to be small and was not estimated.

[3] Forty-one percent of the Quinsam release was not marked.

2.2.1 Robertson Creek Hatchery

Two categories of questions occur at Robertson Hatchery and other indicators. First, there is a question of how accurately the Robertson stock represents west Vancouver Island (wVI) stocks and, second, there are significant measurement errors. The first question will be discussed in the Conclusions. 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 (below Robertson), Robertson data are being scrutinized more and significant inaccuracies seem probable. 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) and will be reviewed this year. Some of these discrepancies are not unique to Robertson (Schnute et al. 1990).

There are three data problems known to exist at Robertson, now or formerly. Up until last year when the procedural and facility problems were changed, the jacks were able to leave the hatchery holding pond after entering and before being counted. This introduced a possible error which would 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. This potential problem has not been addressed. Finally, the hatchery typically barred further entry of coho once brood stock and other requirements had been met. A review will be done of hatchery records to see if an estimate of the excluded coho is possible. Despite the large run in 2000, a special effort was made to process all of it and the intent is to continue this practice. This procedural change may have exaggerated the difference between the large escapement recorded in 2000 and earlier years. We discuss the effect of potentially significant under-estimates of escapement in the following sections.

Pending a review of Robertson data, we have calculated an alternative data set of returns based on the coho counts at Stamp Falls. We estimated total returns to Stamp Falls, using the Stamp Falls counts plus the expanded catch of Robertson coded wire tagged coho. Counts are available since 1986. A new time series of Robertson survivals was generated using Robertson smolt releases and estimating the Robertson return as a constant 85% of the 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 assumption will become clearer with more years of monitoring at the falls in conjunction with mass marking. It is not considered a critical assumption since large relative changes in the minor non-hatchery production will have small effect on results. We refer to this data set as SF85 and the original data set as RCH. They are shown in Table 4. The 1994 brood year (1997 return year) was excluded from survival and abundance time series and sibling analyses because it was an extreme outlier (survival estimated from the sibling regression was 23%). We have no explanation for this anomaly at this time.

2.2.2 Salinity Data

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.

2.2.3 Abundance Forecasts

In southern British Columbia (sBC), all fisheries were managed to eliminate coho mortality wherever possible and to minimize it otherwise. Fisheries that were permitted were assigned mortality[4] ceilings based on forecasts of abundance of Strait of Georgia–Fraser (StG-Fr) and wVI stock aggregates. The StG-Fr aggregate includes stocks originating in streams draining into the Strait of Georgia and Johnstone Strait, including the Fraser and its tributaries. The wVI aggregate is comprised of stocks on the west coast of Vancouver Island. Holtby and Kadowaki (1998) forecast abundance for each aggregate by using catches by fishery and estimates of the stock composition in the fisheries to estimate the catch of the aggregate.

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

Each aggregate catch was divided by the estimated mean exploitation rate of the indicator stocks in the aggregate. A similar method was used to forecast the abundance of coho in the west coast of Vancouver Island (WCVI) troll fishing area (Kadowaki et al. 1996; Kadowaki 1997). We have not been able to do this reconstruction since 1997 because of the minimal catch and the profound changes to fishing patterns caused by the coho conservation measures which began in 1998.

Our method for estimating abundance of the aggregate (A) in 2000 depends directly on estimates of abundance for past years, A_k. We estimated for each of those years the total return to each of the five indicator hatcheries (N_{ik}, i denoting hatchery). The ratio p_{ik} , was then calculated:

$$p_{ik} = \frac{N_{ik}}{A_k} \qquad (1)$$

Estimates of the abundance in 2000 (year t) were then estimated for each hatchery:

$$A_t = \frac{N_{i,t}}{p_i} \qquad (2)$$

where p_i is an average of p_{ik} over either the entire time series or a recent period, n. This provides one estimate for the wVI aggregate and four estimates for the abundance of the StG-Fr aggregate, based on returns to each hatchery indicator in that area. A fifth estimate was made for the StG-Fr aggregate in a corresponding manner by summing returns to the four hatcheries and dividing the total by p, the average annual proportion that the total return to all four hatcheries represented of the estimated abundances in the same time period:

$$A_t = \frac{\sum_{i=1,4} N_{i,t}}{p} \qquad (3)$$

, where

$$p = \frac{\sum_{k=1,n}((\sum_{i=1,4} N_{ik})/A_k)}{n} \qquad (4)$$

This method assumes that past estimates of A and N_i were accurate and that the hatchery proportion of the total abundance has not changed.

Under-estimated escapement counts in the RCH data set will increase exploitation estimates for Robertson and the wVI aggregate. These over-estimates of exploitation result in an under-estimation of abundance for the wVI aggregate because pre-1998 abundances were calculated as the catch of wVI coho divided by the Robertson exploitation rate. Under-estimated escapements would also decrease the abundance estimates in 1998 and 1999 because the estimate of total stock size (N_t) of Robertson is reduced.

3. Forecasting Models and Retrospective Analysis of Predictive Power

3.1 Forecasting Models

3.1.1 Time Series

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

$$Z_t = \Im(v_t) \qquad (5)$$

The Log transformation was used for abundance. The Logit transformation[5] 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")	$Z_{t+1} = Z_t + \varepsilon_t$	(6)
3YRA (3-year average)	$Z_{t+1} = \dfrac{\sum_{k=t-2,t} Z_k}{3} + \varepsilon_t$	(7)
RAT1 (1 year trend)	$Z_{t+1} = \dfrac{Z_t^2}{Z_{t-1}} + \varepsilon_t$	(8)
RAT3 (average 3-year trend)	$Z_{t+1} = \dfrac{\sum_{k=t-2,t} Z_k / Z_{k-1}}{3} Z_t + \varepsilon_t$	(9)

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 $1\ldots t$.

[5]The Logit transformation, $Z_t = \ln\left(\dfrac{v_t}{1-v_t}\right)$, 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.

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 ($R_{x.1}^{t}$) is predicted from the observed x.0 male escapement in the previous year ($R_{x.0}^{t-1}$, 'jacks'):

$$\ln R_{x.1}^{t} = b \ln R_{x.0}^{t-1} + a \qquad (10)$$

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

3.1.3 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 we use of distribution 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 and 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 (Holtby and Kadowaki 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 in the year of return at Sisters and Chrome Island lighthouses in the central Strait of Georgia are correlated with p_{inside}. Salinity in February of the year of return is the best predictor of p_{inside}. Kadowaki (1997) averaged the daily February values from each lighthouse and then averaged the two means. Kadowaki et al. (1996) and Holtby and Kadowaki (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. These salinity's are negatively correlated with the discharge of the Fraser River in February (Beamish et al. 1999).

Catch distribution or the proportion of the catch (p_{inside}) that would be caught in waters inside the Strait of Georgia under fishing patterns observed prior to 1997 was estimated using the model:

$$Logit(p_{inside}) = bS + a \qquad (11)$$

where S is the average February surface salinity at Chrome Island and Sisters in the adult return year. Confidence limits around the sibling and salinity forecasts were determined using linear regression analysis.

3.1.4 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 in Barkley Sound have undergone marked declines in recent years (Tanasichuk, *in press*). This prompted us to examine in the previous forecast papers (Holtby et al. 1999,2000) the relationship between the marine survival of Robertson Creek coho in year *t* with the abundance of *Thysanoessa spinifera* in Barkley Sound in their smolt year, year *t-1*. We include a forecast of survival of Carnation Creek coho in this report. Carnation Creek survival estimates are calculated assuming exploitation rates equal to Robertson Creek Hatchery coho. This was probably a reasonable assumption before 1998 when the major fishery was WCVI troll and since then violations of the assumption, although more likely, are not considered significant since exploitations are very low. A forecast for Carnation is particularly pertinent now with our increasing uncertainty about Robertson escapement data.

Collection and processing protocols for euphausiids are fully described in Tanasichuk (1998). The measure of abundance used here is the median number per m^2 from June to August 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). Nine observations were available (Table 5).

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*):

$$RMSE = \sqrt{\overline{(v_{observed,k} - v_{predicted,k})^2}} \qquad (12)$$

and the Mean Absolute Deviation (*MAD*):

$$MAD = \overline{\left|(v_{observed,k} - v_{predicted,k})\right|} \qquad (13)$$

Note that this calculation is performed in the variable space and not in the transformed (equation 5) space.

4. Forecasts of Marine Survival

4.1 Forecast Performance in 2000

Preliminary estimates of marine survival in 2000 are shown in Table 3 and Figure 1 for the five hatchery indicators and two wild indicators. Survivals would have been slightly higher than these estimates because they do not include (1) Washington catches and (2) release mortalities from non-retention fisheries in southern British Columbia and Washington. Marine survival in 1999 and 2000 are compared in the following table:

	Marine Survival		
	1999	2000	Relative Change
Quinsam	0.008	0.017	106
Black (wild)	0.017	0.022	29
Big Qualicum	0.011	0.020	78
Chilliwack	0.015	0.023	53
Inch	0.020	0.014	-30
Average StG-Fr	0.014	0.019	34
Robertson - RCH	0.021	0.076	264
- SF85	0.044	0.098	121
Carnation (wild)	0.010	0.048	380

The fairly steady downward trend in survivals of indicator stocks in the Georgia Basin, which began in the 1989 to 1992 period, was partially broken in 1999 and survivals generally increased in 2000 (but remained very poor). The only decline was at Inch Creek. The survival of Black Creek coho improved slightly after a large decrease from 1998 to 1999. The 2.2% survival there remains the second lowest seen in the 1986-2000 time series. Preliminary indications of escapement to streams around the Strait of Georgia largely support a conclusion that survivals of wild coho improved but remained poor.

There was a large increase in the survival of Robertson coho in the wVI area. Survival estimated with the RCH data was 7.6%, well above the pre-2000 mean of 4.1%. As noted earlier, an unknown part of the survival increase may have been due to the new objective in 2000 of brailing late season coho. In some previous years, unknown numbers of these coho were not brailed, counted and sampled, i.e. the pre-2000 mean escapement is an under-estimate. Trends in Robertson survival since 1986 are similar using the two estimates of hatchery escapement but SF85 survivals, almost always higher than RCH survivals, are higher to a variable extent (Figure 2). The 1999 to 2000 increase in Robertson survivals using the SF85 set was about half as great.

The 264% increase in survival from 1999 to 2000 using the RCH data was still exceeded by the survival increase at Carnation Creek, which more than tripled (Table 3). However, survival of Carnation coho was only 1% in 1999 so even with this increase the 2000 survival was only 4.8%.

The performance of the 2000 forecasts (Holtby et al. 2000) is summarized in the following table, in Table 6 and on Figure 1. The best performing models are shaded, i.e. the models with the least RMSE's and MAD's. Of the forecasts selected from the suite of time series and sibling regression models for each indicator, most predicted lower survivals than were subsequently observed. The exceptions were for Black and Inch Creek coho, where observed survivals were lower than forecast. Under-forecasts were large for Quinsam and Chilliwack returns and especially large for the Robertson return, where the sibling model was used. The observed survival of Robertson coho was at the 95th percentile of the forecast. Survival at Robertson Creek was not well predicted by the euphausiid model either. The euphausiid forecast was 0.019 or 25% of the observed survival.

	Quinsam	Black	Big Qualicum	Chilliwack	Inch	Robertson[1]
Observed survival, 2000	0.017	0.022	0.020	0.023	0.014	0.076
Sibling forecast	0.026	-	0.012	0.008	0.040	0.033
% forecast of observed[2]	158%	-	61%	35%	286%	43%
Quasi TS model						
Forecast	0.010	0.033	0.015	0.014	0.019	0.021
% forecast of observed[2]	61%	151%	77%	61%	136%	27%

[1] The observed survival was calculated using escapement recorded at RCH.

[2] Previous forecast papers, e.g. Holtby et al. (2000), used % observed of forecast.

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 autocorrelation 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 2001

4.2.1 Euphausiid Model

A strong relationship exists between arcsine transformed survivals of Robertson coho, using either the RCH or SF85 data sets (Table 4), and the euphausiid abundance data (Table 5). Figure 3 and Table 7 show the following fits of von Bertalanffy growth curves to the RCH survival data for Robertson coho and to survivals of Carnation coho, the latter being based on RCH-derived estimates of Carnation catches:

Robertson Creek Hatchery:

$$\sin^{-1}\sqrt{s} = 0.2004(1 - e^{-0.0802E}) \qquad (14)$$

($N = 9$; adj. $r^2 = 0.73$; $P < 0.001$)

Carnation Creek:

$$\sin^{-1}\sqrt{s} = 0.3256(1 - e^{-0.0592E}) \qquad (15)$$

($N = 9$; adj. $r^2 = 0.82$; $P < 0.001$)

where s is marine survival and E is euphausiid abundance.

4.2.2 All Models

Besides the euphausiid regression forecast in Table 7, survival forecasts and associated confidence intervals are shown for the sibling regressions in Table 8 and for the time-series models in Table 9. The survival forecasts made by the best performing model and associated 50% confidence intervals are summarized in the following table and in Figures 4 and 5:

		Best Models		Alternate Regression Models		
		$\hat{S}_{2001}$	(50% CI)	Data	$\hat{S}_{2001}$	(50% CI)
Big Qualicum	LLY	0.020	(0.012 - 0.031)	Sibling	0.027	(0.016 - 0.046)
Quinsam	3YRA	0.011	(0.008 - 0.014)	Sibling	0.021	(0.014 - 0.032)
Chilliwack	RAT3	0.014	(0.011 - 0.019)	Sibling	0.055	(0.034 - 0.087)
Inch	3YRA	0.012	(0.006 - 0.023)	Sibling	0.043	(0.026 - 0.072)
Black	3YRA	0.026	(0.021 - 0.033)		-	
Robertson:	Sibling, RCH	0.039	(0.026 - 0.059)	Sibling, SF85	0.054	(0.037 - 0.077)
	Euphausiid, RCH	0.040	(0.021 - 0.063)	Euphausiid, SF85	0.058	(0.032 - 0.092)
Carnation	Euphausiid, RCH[1]	0.102	(0.066 - 0.143)	Euphausiid, SF85[1]	0.075	(0.052 - 0.101)

[1] Estimates of survival of Carnation coho require Robertson estimates of exploitation rates, which depend on whether the RCH or SF85 data are used.

The outlook for the Georgia Basin indicators is for poor survivals, similar to or less than 2000. The auto-correlated survivals in the 1990's stopped trending down in 1999 and 2000 so there is increased uncertainty with the trend models, RAT1 and RAT3. The Chilliwack forecast uses the RAT3 model but survivals there began increasing in 1999 so only the first of the three inter-annual trends used in the calculation (1998-1999) was part of the old downward trend. For that reason, we accepted the forecast (0.014) but suspect it may be low. The LLY and 3YRA forecasts are 2.3% and 1.7% respectively. The survival of Black Creek coho is forecast to be 2.6%, but this model significantly over-forecast survival in 1999 and 2000.

For Robertson Creek coho, the sibling-regression model using RCH escapements (Figure 5) predicts survival will be 3.9%, similar to the mean survival from 1991 to 2000, which was 3.2%. This is significantly less than the 7.6% survival seen last year. Virtually the same forecast is obtained using the euphausiid model (4.0%). The sibling/RCH model over-forecast the 1998 and 1999 survivals and badly under-forecast the 2000 survival while the euphausiid model accurately predicted RCH survival in 1999 but under-forecast the 2000 survival even more than the sibling model.

One factor in the poor forecasts last year may be the change to more complete counts at the hatchery, although the return seen at Stamp Falls was also larger than expected. We compared sibling regressions of Stamp Falls jacks vs. Stamp Falls adults, RCH jacks vs. Stamp Falls adults and the usual RCH jacks vs. RCH adults. The sibling and euphausiid forecasts are also similar when SF85 data are used. The survival forecast for Robertson coho using the SF85 data is shown in Figure 6. While the SF85 predictions are for higher survivals by a difference of 1.4% to 1.9%, the mean survival from 1991 to 2000 in the SF85 time series is 4.8%. Therefore, the prediction is the same as the RCH prediction in relative terms: a 2001 survival slightly greater than the mean survival seen through the 1990's but less than last year.

Carnation Creek has the advantage of accurate estimates of escapement. It lacks direct estimates of exploitation as already explained. Being a wild stock, sibling relationships are absent at Carnation, like they are at Black. We have applied the euphausiid model using exploitations derived from the RCH and SF85 data and did the time series analysis using the longer RCH time series of data. The best time series model was the 3YRA (Table 9). However, its RMSE performance was much worse than the euphausiid model for the period of euphausiid measurements (1989 to 1997 brood years). Time series models have also not been successful in forecasting Robertson survivals. The euphausiid forecasts using RCH and SF85 data of 10.2% (50% CI: 6.6%-14.3%) and 7.5% (50% CI: 5.2%-10.1%), respectively, are higher than

Robertson. Wild coho usually survive better than neighboring hatchery coho (last year being an exception with the high Robertson survival). These forecasts are for above average survivals: the mean survivals for 1991 to 2000 based on RCH and SF85 derived exploitations are 7.3% and 5.6%, respectively.

5. Forecast of Distribution

The forecast of catch proportion inside is:

$$\log it(\hat{p}_{inside}) = 1.002GSsal - 28.9 \quad (15)$$

(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 29.63 ‰. Only one salinity has been higher since before 1975 (in 1988). Figure 7 shows the fitted relationship and a probability plot of the confidence interval for p_{inside}. Confidence levels are tabulated in Table 10. The predicted value of 0.70 is indicative of a very strong inside distribution. The confidence intervals indicate that the probability of even a moderate outside year ($p_{inside} < 0.3$) is less than 1%.

It is important to note that Strait of Georgia-Fraser stocks vary in their proclivity to be in the Strait in their final ocean year. From January to August of 1993, which was the last 'inside' year for the aggregate as a whole, 40% of the estimated recoveries of tagged interior Fraser stocks were recovered outside of the Strait, particularly in WCVI fisheries. Hence, a significant proportion of Thompson and other interior Fraser coho can be expected to occur in the wVI area in 2001.

6. Forecasts of Abundance

6.1 Forecast Performance in 2000

The estimated abundance in 2000 of coho in the Strait of Georgia – Fraser aggregate was 560,000 (Table 11 and Figure 8). The abundance was forecast to be only 250,000 (Table 12). The estimated abundance falls outside the 95th percentile of the forecast. The estimate of wVI abundance of 920,000 using the RCH data is much higher than the forecast abundance of 270,000 (greater than the 99th percentile of the CI (Table 12)). Obviously, abundance was not well forecast in either area.

The wVI abundance estimate entirely relies on the total return to Robertson Hatchery. Escapements to wVI streams only increased an average of 6% in 2000. This contrasts with the 3.5 times increase in spawners counted at the hatchery. The escapement to Carnation Creek in 2000 was 129, 2.7 times the escapement in 1999 of 47 coho. Despite these increases in the two indicators, we think the estimated increase in abundance from 260,000 to 920,000 is too large, based on escapements in the rest of the area. Dobson et al. (2000) describe the escapement monitoring program.

A new time series of abundances was calculated for 1986 to 1997 using the Holtby and Kadowaki (1998) procedure and revised exploitation rates based on the SF85 data (Table 11, Figure 8). Abundances for 1998 to 2000 were calculated as explained in Sect. 2.2.3 using the historic proportion of wVI abundance originating from Robertson and the SF85 return data. There is a 98% increase in abundances from 1999 to 2000 in this data set, corresponding to the same increase in the Stamp Falls return. Although closer to the change in escapements seen elsewhere, the increase in abundance estimates is still much larger than field data indicate for other stocks, excepting Carnation. This is a reflection of a substantially larger increase in the Somass (Stamp Falls) escapement than seen in most other escapements. Past escapements into the Somass system are correlated with Carnation Creek and Gold River escapements (Dobson et al. 2000).

6.2 Forecast Abundance in 2001

The four time series models were used to forecast abundance in 2001 for StG-Fr and wVI aggregates. For the first time since 1993, the abundance of the StG-Fr aggregate significantly increased in 2000 (Figure 8). From 1993 to 2000, the best performing model has been the RAT3 model. The LLY model is better this year, reflecting the trend reversal. Therefore the forecast StG-Fr abundance for 2001 is for no change: 560,000 (50% CI: 430,000–730,000; Table 13). A probability distribution of this forecast is shown in Figure 9.

For the wVI aggregate, the 3YRA model was the best performer over the period 1990-2000 for both RCH and SF85 data sets. The RCH forecast is 470,000 (50% CI: 320,000 – 690,000, Table 13). The SF85 forecast performance is poorer (RMSE: 470,000 vs. 250,000 for the RCH data) and the estimate is not as conservative: 690,000 (50% CI: 450,000 – 1,100,000). We favor the RCH forecast. Its probability distribution is shown in Figure 9.

6.3 Interior Fraser Coho

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

In retrospective analysis, the averaging models (LLY and 3YRA) outperformed the ratio models in forecasting total returns to Thompson systems (Table 14). The 3YRA model continues to be the model of choice for the Thompson watershed. Our time series of reliable escapement data for non-Thompson systems in the interior Fraser is too short to evaluate model performance. The time series of abundances for coho in the Thompson River watershed is shown in Figure 10.

Forecasts of total abundance for 2000 provided in last year's forecast document (Holtby et al. 2000) were evaluated by comparing these forecasts with estimated coho abundance (i.e. observed, Table 15). The 3YRA model underestimated abundance of South Thompson coho by ~13% and overestimated North Thompson abundance by ~15%. The overall forecast for interior Fraser coho was reasonably accurate (~22,000 forecast and ~20,700 coho observed). This is probably somewhat fortuitous, as we are still not confident in our estimates of some non-Thompson systems.

The abundance (i.e. catch plus escapement including fish taken for brood stock) of Thompson watershed coho in 2000 was ~15,800 (Table 2). Thompson coho abundance in 2000 was less than the brood (1997) abundance (~21,750), but 2000 Thompson escapements (~15,300) exceeded 1997 escapements (~13,000) because of reductions in the fishery.

We forecast that the abundance of Thompson River coho in 2001 will exceed observed abundances in 2000 (Table 16; Figure 10). Using the 3YRA model, we predict ~17,500 coho will survive to adulthood and be available to return to the Thompson River watershed. The forecast returns to the Thompson are approximately 20% of the mean abundance. We are unable to forecast returns to non-Thompson streams due to the extremely short time series of reliable escapement data (n=3).

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 2001 (50% CI)	Change (2001 forecast minus 2000 observed S)
Big Qualicum	LLY	0.020 (0.012 - 0.031)	0.000
Quinsam	3YRA	0.011 (0.008 - 0.014)	-0.006
Chilliwack	RAT3	0.014 (0.011 - 0.019)	-0.009
Inch	3YRA	0.012 (0.006 - 0.023)	-0.002
Black Creek	3YRA	0.026 (0.021 - 0.033)	0.004
Robertson:	Sibling, RCH	0.039 (0.026 - 0.059)	-0.037
	Euphausiid,RCH	0.040 (0.021 - 0.063)	-0.036
Carnation Creek	Euphausiid, RCH	0.102 (0.066 - 0.143)	0.054

For populations around the Strait of Georgia, survivals are forecast to change very little. Survival will remain poor throughout southern BC and survival is forecast to improve only marginally at Black Creek. None of the sibling models performed better than the statistical models. However, they consistently predict better survivals. Differences are 1% or less for Big Qualicum and Quinsam but larger in the lower Fraser (Inch and Chilliwack). For Chilliwack coho, the sibling forecast is 5.5% and the selected RAT3 model predicts 1.4%. From the pattern of recent survivals at Chilliwack we think 1.4% may be an under-estimate but, with the performance of the sibling forecast historically so much poorer (RMSE: 0.046 vs. 0.021) we have no firm basis for selecting the sibling forecast. The sibling forecast for Inch coho is 4.3% vs. the selected time series forecast of 1.2% and for this stock the RMSE difference is not as great (sibling: 0.036 vs. 0.027).

Marine catches in 2000 suggest that the abundance of the 1998 brood was larger than the two previous broods and individuals were larger (R. Beamish, C. Neville and G. McFarlane, personal comm.). Beamish et al. attribute larger catches primarily to an increase in survival, based on measurements of the hatchery: wild composition in the catches, which indicated only a slight increase in wild recruitment. The larger size last fall may also contribute to improved survival. These data and jack returns in 2000 therefore suggest that forecasts are more likely be underestimates than overestimates.

Euphausiid and sibling survival forecasts are presented for Robertson Creek coho on the west coast of Vancouver Island, both utilizing the same time series as has been used before. Bearing in mind that both badly under-forecast the 2000 survival of 7.6%, both predict a survival in 2001 that is similar to the mean 1990's survival and about half of last year's unusually large survival. Using an alternate estimate of Robertson escapements resulted in larger survivals in the time series, including a larger forecast, but the 2001 forecast remains in the same proportion to last year and the 10-year average.

Carnation Creek has been added to the forecast this year. It has the advantage of accurate escapement counts and we do not regard the need to estimate its catch using Robertson exploitation rates as a serious impediment. The euphausiid forecast survival of 10.2% is an increase over the 4.8% last year and is better than the 1990's average of 8.4%.

7.2 Abundance

Forecasting abundance is highly problematic and, because we are using time-series models, the forecast is dependent on the highly uncertain estimates of abundance since 1998. Abundance was estimated to be 560,000 for populations in the Georgia Basin, which is more than the upper 95% confidence limit for the forecasted abundance of 250,000. This year the best model is the LLY model, meaning we are forecasting no change in abundance, similar to the forecast for survivals. An abundance of 560,000 is 40 % of the long term mean abundance of 1.4 million.

The estimated abundance of the wVI aggregate in 2000 (920,000) was extreme compared to the forecast (270,000; upper 99% confidence limit: 900,000). This was attributable to a very large escapement to the hatchery. Although there was also a large relative increase in the escapement to Carnation Creek, all our other escapement data for wVI indicated only a slight improvement in abundance. This stimulated us to examine the effect of using Stamp Falls counts as an alternate estimate of Robertson escapement, which were underestimated before 2000 but to an unknown degree. Using this data the abundance estimate for 2000 was slightly higher (1.15 million). However, estimated abundances in 1999 and in many preceding years were higher yet so the difference from 1999 to 2000, although still large, was about half the difference using hatchery escapements. Escapement in 2000 to the Somass system, including Robertson, was obviously large compared to most other wVI areas. Normally, Somass escapements correlate with Gold River counts as well as Carnation escapements. This occurrence highlights the vulnerability of wVI forecasts, based on only one indicator. Kirby Creek, near Sooke, is underway as a wild indicator and we will begin obtaining catch estimates from Carnation by coded wire tagging this year. The forecast of wVI abundance in 2001, based on the 3YRA of abundances, is for 460,000 (50% CI: 310,000 – 670,000). The 2000 estimate and 2001 forecast represent 175% and 84% of the long term mean abundances, respectively. The forecast total abundance of Thompson River watershed coho in 2001 is ~17,500, similar to the estimated abundance in the brood year and only about 20% of the long term mean abundance. The overall abundance of Thompson coho has not increased significantly in recent years, but spawner numbers are increasing. Escapements in 2000 and 1999 were both 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.

7.3 Distribution

In the hypothetical circumstance of historical patterns of fishing, the predicted proportion of catch inside the Strait of Georgia (p_{inside}) would be 0.70 (50% CI: 0.60 - 0.78), which can be characterized as a very strong inside distribution. The confidence interval indicates that there is less than a 1% chance of a moderate outside year occurring if that is defined as $p_{inside} < 0.3$. Age x.1 coho are now present in the Victoria area (T. Gjernes, pers. comm.) and near French Creek (D. Heller and T. Gjernes, pers. comm.). These sightings do not occur in an 'outside' year. Twenty-one trawl sets in November and January in the Strait of Georgia and Juan de Fuca Strait yielded relatively few coho (D. Beamish, C. Neville and G. McFarlane, pers comm.). However, this is not contradictory evidence if a significant portion of the Strait of Georgia population normally leaves the Strait in the early fall and an 'inside' or 'outside' year depends on whether they return in late winter.

The forecast inside distribution is for the aggregate as a whole. Thompson and Cowichan coho are known to have a stronger predilection for rearing outside in their second year and significant proportions will probably occur in both inside and outside waters this year.

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Table 1. 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 R (lwr)	W	Albreda R	W
Bridge River	W	Nicola River (lower)	W	Adams R (up)	W	Avola Cr	W
Chilko River	W	Nicola River (upper)	W	Anstey River	W	Barrierre R	W
McKinley Creek	W	Tranquille Creek	W	Bessette Cr	W	Blue R	W
Mitchell River	W	Coldwater River	E	Blurton Cr	W	Brookfield. Cr	W
Nahatlatch River	W	Deadman River	E	Bolean Cr	W	Cedar Cr	W
Portage Creek	W	Spius Creek	E	Canoe Cr	W	Clearwater. R	W
Cayoosh Creek	W			Cayenne C	W	Cook Cr	W
Seton River	W			Creighton Cr	W	Crossing Cr	W
Summit Creek	W			Danforth Creek	W	E. Barrierre. R	W
				Duteau Cr	W	Fennel Cr	W
				Harris Cr	W	Finn Cr	W
				Huihill Cr	W	Goose Cr	W
				Hunakwa Cr	W	Haggard Cr	W
				Ireland Cr	W	Lion Cr	W
				Johnson Cr	W	Mahood R	W
				Kingfisher Cr	W	Mann Cr	W
				McNomee Cr	W	McTag. Cr	W
				Momich Cr	W	N. Thompson R	W
				Noisey Cr	W	Raft R	W
				Onyx Cr	W	Reg Chris. Cr	W
				Owlhead Cr.	W	Shannon Cr	W
				Scotch Cr	W	Tumtum Cr	W
				Seymour R	W	Wireca. Cr	W
				Shuswap R (lwr)	W	Dunn Cr	E
				Shuswap R (mid)	W	Lemieux Cr	E
				Sinmax Cr	W	Louis Cr	E
				South Pass C	W		
				Tappen Cr	W		
				Trinity C	W		
				Wap Cr	W		
				Eagle R	E		
				Salmon R	E		

Table 2. Estimated fishery exploitation rates (expl), escapements (esc), marine fishery catches and total abundances (abund) for the interior Fraser coho salmon.

Return		South Thompson			North Thompson			Lower Thompson			Non-Thompson Fraser		
Year	expl	esc	catch	abund	esc	catch	abund	esc	catch	abund	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	0.03	3785	134	3919	7032	250	7282	4459	157	4616	4723	144	4867

Table 3. Release and recovery summaries for the seven indicator streams used to generate forecasts.

Brood Year	CWT smolt release[1]	Estimated Return age x.0 (jacks)	Estimated Return age x.1	Marine Survival Rate (age x.1)
Big Qualicum				
1972	113018	1398	40122	0.355
1973	57425	928	16584	0.289
1974	75512	1481	12366	0.164
1975	210520	5858	28029	0.133
1976	150348	1511	28427	0.189
1977	101224	620	21439	0.212
1978	107328	543	12176	0.113
1979	55435	732	5706	0.103
1980	51984	271	5792	0.111
1981	49274	643	3882	0.079
1982	42453	181	2129	0.050
1983	21868	33	188	0.009
1984	87365	71	544	0.006
1985	74194	440	1112	0.015
1986	27462	95	356	0.013
1987	42412	388	1814	0.043
1988	44813	246	2758	0.062
1989	36474	186	2135	0.059
1990	37362	363	2497	0.067
1991	38235	188	2617	0.068
1992	37957	48	1116	0.029
1993	38917	237	621	0.016
1994	37616	87	535	0.014
1995	38827	41	173	0.004
1996	40331	144	448	0.011
1997	37806	64	740	0.020
1998	40836	135		
Chilliwack				
1980	54665	585	6543	0.120
1981	28502	408	4090	0.143
1982	100841	757	18865	0.187
1983	27851	153	3664	0.132
1984	129770	554	22536	0.174
1985	59935	844	10847	0.181
1986	68658	350	8698	0.127
1987	39250	269	4166	0.106
1988	39801	233	3605	0.091
1989	39500	151	2245	0.057
1990	39797	152	2360	0.059
1991	39673	87	2536	0.064
1992	39654	153	1480	0.037
1993	39808	206	1584	0.040
1994	36256	75	899	0.025
1995	74456	130	1001	0.013
1996	37282	43	555	0.015
1997	82059	42	1463	0.023
1998	36976	112		

Brood Year	CWT smolt release[1]	Estimated Return		Marine Survival Rate (age x.1)
		age x.0 (jacks)	age x.1	
Inch Creek				
1983	38711	26	2562	0.066
1984	38774	197	3442	0.089
1985	19723	149	4007	0.203
1986	19504	21	2121	0.109
1987	27458	126	2203	0.080
1988	38019	36	2690	0.071
1989	29367	37	2850	0.097
1990	31629	101	2608	0.082
1991	21172	111	1282	0.061
1992	20303	10	1115	0.055
1993	21540	90	835	0.039
1994	21174	5	225	0.011
1995	38707	12	243	0.006
1996	41918	7	828	0.020
1997	60313	73	844	0.014
1998	40201	63		
Quinsam				
1975	97560	2205	7130	0.073
1976	159136	3243	9302	0.058
1977	168286	2178	16784	0.100
1978	226186	2308	12614	0.056
1979	280127	3118	13393	0.048
1980	57385	410	4033	0.070
1981	102021	660	5541	0.054
1982	147404	1132	11182	0.076
1983	57764	514	6567	0.114
1984	57573	726	4515	0.078
1985	42176	925	3352	0.079
1986	44457	847	4731	0.106
1987	39362	792	3067	0.078
1988	39466	298	1649	0.042
1989	39400	250	2312	0.059
1990	39411	233	1367	0.035
1991	42470	315	964	0.023
1992	36277	276	910	0.025
1993	38947	128	535	0.014
1994	80125	247	949	0.012
1995	82351	644	780	0.009
1996	39813	90	332	0.008
1997	39322	202	649	0.017
1998	42321	188		
Black Creek (wild indicator)				
1983	24134	95	3016	0.125
1984	31648	46	3617	0.114
1985	35640	455	4510	0.127
1986	74997	305	8529	0.114
1987	29203	559	3628	0.124
1988	118382	824	9028	0.076
1989	52351	1837	6399	0.122
1990	49860	1710	3156	0.063
1991	54996	757	3162	0.057
1992	75970	1214	3459	0.046
1993	18152	1079	611	0.034
1994	13736	280	599	0.044
1995	69996	242	3346	0.048
1996	24637		415	0.017

Brood Year	CWT smolt release[1]	Estimated Return age x.0 (jacks)	Estimated Return age x.1	Marine Survival Rate (age x.1)
Black Creek (continued)				
1997	26247		575	0.022
1998	151129			
Robertson Creek[2]				
1973	44071	1231	3415	0.077
1974	55672	1055	4011	0.072
1975	51460	1628	2515	0.049
1976	43047	486	3773	0.088
1977	51019	433	2373	0.047
1978	51916	307	1168	0.022
1979	48776	110	975	0.020
1980	144742	1037	8193	0.057
1981	125895	1055	8657	0.069
1982	94740	44	1932	0.020
1983	52092	85	2038	0.039
1984	46061	54	1335	0.029
1985	41474	85	765	0.018
1986	50967	412	2514	0.049
1987	61191	616	5525	0.090
1988	43524	140	2567	0.059
1989	41773	57	1926	0.046
1990	40221	140	963	0.024
1991	38419	0	18	0.000
1992	36873	2	464	0.013
1993	42248	23	755	0.018
1994	43005	228	1310	0.030
1995	39566	54	1389	0.035
1996	39578	57	834	0.021
1997	40499	67	3096	0.076
1998	40207	92		
Carnation Creek (wild indicator)[3]				
1972	2658	75	327	0.123
1973	2121	54	260	0.123
1974	3062	35	268	0.088
1975	2560	53	172	0.067
1976	4646	233	708	0.152
1977	3530	114	324	0.092
1978	4567	101	235	0.052
1979	4164	61	525	0.126
1980	3470	61	321	0.092
1981	3745	83	200	0.053
1982	3113	25	188	0.060
1983	1978	59	323	0.163
1984	2833	27	143	0.050
1985	2648	58	204	0.077
1986	2712	98	514	0.190
1987	3862	160	599	0.155
1988	3222	128	609	0.189
1989	3103	51	385	0.124
1990	5253	43	388	0.074
1991	3989	6	24	0.006
1992	4759	104	432	0.091
1993	3480	90	165	0.047

Brood Year	CWT smolt release[1]	Estimated Return		Marine Survival Rate (age x.1)
		age x.0 (jacks)	age x.1	
Carnation Creek (continued)				
1994	892	85	76	0.085
1995	4942	1995	293	0.059
1996	4865	69	49	0.010
1997	2842	79	136	0.048
1998	4828	86		

[1]After 1995, marine survival rate is calculated only from CWT-ad groups. Carnation and Black smolt abundances include some age 2.0 smolts from the previous brood year.

[2] Return estimates use hatchery records of escapement (the RCH data set).

[3] The catch component of Carnation returns and survivals are estimated by assuming exploitations equal to Robertson Hatchery (RCH data set).

Table 4. Comparison of escapement, survival and exploitation estimates of Robertson Creek Hatchery coho using escapements recorded at the hatchery (RCH data set) and escapements estimated as 85% of the Stamp Falls fishway counts (SF*.85). Catches and RCH escapements are based on expanded CWT recoveries (cf. estimated recoveries in Table 3).

Return Year	Number	Stamp Falls Count		SF*.85		RCH Escapement		CWT	SF 85		RCH	
	Released	Jacks	Adults	Jacks	Adults	Jacks	Adults	Catch*	ER	SR	ER	SR**
1986	1,601,236		27,195		23,116	1,302	23,294	41,411	0.64	0.040	0.64	0.039
1987	1,459,566		17,050		14,493	2,385	18,387	24,533	0.63	0.027	0.57	0.029
1988	1,155,807	1,735	10,594	1,475	9,005	8,896	5,943	15,354	0.63	0.021	0.72	0.018
1989	1,144,494	4,633	33,886	3,938	28,803	5,268	16,659	40,243	0.58	0.060	0.71	0.049
1990	547,233	5,331	45,441	4,531	38,625	3,800	15,648	33,593	0.47	0.132	0.68	0.089
1991	1,195,149	7,572	37,949	6,436	32,257	2,113	23,990	45,226	0.58	0.065	0.65	0.058
1992	1,548,640	7,568	50,148	6,433	42,626	4,875	19,649	51,980	0.55	0.061	0.73	0.046
1993	1,428,737	861	15,480	732	13,158	0	7,693	25,722	0.66	0.027	0.77	0.024
1994	770,779	2,986	977	2,538	830	42	141	232	0.22	0.001	0.62	0.000
1995	775,457	3,198	18,380	2,718	15,623	439	3,946	5,796	0.27	0.028	0.59	0.013
1996	807,278	3,885	15,665	3,302	13,315	685	6,452	7,945	0.37	0.026	0.55	0.018
1997	129,570	3,315	6,496	2,818	5,522	1,169	2,556	1,397	0.20	0.053	0.35	0.030
1998	863,524	5,005	70,711	4,254	60,104	1,045	29,363	1,079	0.02	0.071	0.04	0.035
1999	934,097	9,124	46,379	7,755	39,422	1,462	16,601	694	0.02	0.043	0.04	0.018

* Survival estimates for both time series use CWT-derived catch from all tag groups.

** Survival for RCH time series is based on expanded CWT recoveries of all tag groups - survivals may differ slightly from other survivals in the report, e.g. in 1999, which used recoveries of CWT-ad groups.

Table 5. Data used for the biologically based survival forecast for Robertson Creek coho. The euphausiid abundance is the median June to August abundance of *Thysanoessa spinifera* in Barkley Sound in the smolt year. The marine survival data are from Table 3. Survivals of Carnation Creek coho used estimates of catch based on Robertson RCH exploitation rates.

Return Year	Euphausiid Abundance (Median no/m^2)	Robertson Creek Hatchery Survival	Carnation Creek Survival
1992	87	0.046	0.124
1993	33	0.023	0.074
1994	12	0.000	0.006
1995	11	0.013	0.091
1996	15.5	0.018	0.047
1997	82.5	0.031	0.085
1998	28	0.035	0.059
1999	12.5	0.018	0.010
2000	18	0.076	0.048
2001	97		

Table 6. Performance of survival forecasts for 2000, showing the model, the observed survival and the forecast with confidence intervals.

	Strait of Georgia indicator					WCVI Indicator
	Quinsam River	Big Qualicum River	Chilliwack River	Inch Creek	Black Creek (wild)	Robertson Creek
Survival 2000 (obs)	**0.017**	**0.02**	**0.023**	**0.014**	**0.022**	**0.076**
Model	LLY	LLY	RAT3	LLY	3YRA	Sibling
CI:75% [1]	0.0155	0.039	0.025	0.04	0.046	0.046
forecast	**0.0096**	**0.015**	**0.014**	**0.019**	**0.033**	**0.033**
CI:25%	0.0059	0.006	0.008	0.009	0.024	0.023
CI:10%	0.0038	0.002	0.005	0.004	0.017	0.017
CI:5%	0.0029	0.0013	0.003	0.003	0.014	0.014
CI:1%	0.0016	0.0004	0.0015	0.001	0.009	0.009

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

Table 7. Forecasts of marine survival of coho from Robertson Creek Hatchery and Carnation Creek using the euphausiid model[†].

Parameter	Robertson Cr. Hatchery	Carnation Creek
a	0.2004	0.32563
b	-0.0802	-0.05919
N	9	9
Confidence Intervals:		
1% lower	0.004	0.000
5% lower	0.000	0.013
10% lower	0.003	0.024
25% lower	0.011	0.044
Forecast	**0.040**	**0.102**
75% lower	0.084	0.179
90% lower	0.113	0.225
95% lower	0.136	0.261
99% lower	0.200	0.355

[†] The fitted model was $\sin^{-1}\sqrt{s} = a(1-e^{-bE})$ where s is adult survival in year t and E is the median euphausiid abundance between June and August in the smolt year (t-1).

Table 8. Forecast of adult return and survival for the 1998 brood year for the four Strait of Georgia indicators and Robertson Creek using sibling regressions. Data used are found in Table 3. The slope and intercept are for the sibling regression model (Equation 10). The 'SF85' or Stamp Falls regression is presented as an alternative to the Robertson Creek (RCH) regression, which used data which have likely underestimated Robertson Creek Hatchery escapement.

Parameter	Big Qualicum	Chilliwack	Quinsam	Inch	Robertson RCH	Robertson SF85
a (intercept)	1.537	3.452	1.523	5.423	5.752	7.722
b (slope)	1.115	0.882	1.009	0.493	0.355	0.408
N	26	18	23	15	25	13
r^2 adj.	0.78	0.59	0.78	0.38	0.56	0.81
1998 Brood Year:						
CWT-Ad release	40,836	36,976	42,321	40,201	40,207	982,708*
Jack Return (2000)	135	112	188	63	92	2,249
Predicted Adult Return (2001)	1,104	2,026	904	1,747	1,567	52,785
Predicted Survival (2001)	**0.027**	**0.055**	**0.021**	**0.043**	**0.039**	**0.054**
Confidence Intervals:						
1%	0.004	0.010	0.005	0.006	0.009	0.013
5%	0.007	0.017	0.008	0.012	0.014	0.021
10%	0.010	0.022	0.010	0.016	0.018	0.027
25%	0.016	0.034	0.014	0.026	0.026	0.037
75%	0.046	0.087	0.032	0.072	0.058	0.077

* The Stamp Falls regression predicts the total hatchery return, therefore the total 1998 smolt release and expanded jack return are given. The 1994 BY is excluded as an outlier.

Table 9. Time series forecasts of survival of age x.1 coho returning to southern BC indicators in 2001.

	Strait of Georgia Indicator					WCVI Indicator	
	Quinsam River	Big Qualicum River	Chilliwack River	Inch Creek	Black Creek (wild)	Robertson Creek	Carnation Creek (wild)
Model	3YRA	LLY	RAT3	3YRA	3YRA	LLY	3YRA
CI:75%	0.014	0.031	0.019	0.023	0.033	0.162	0.058
forecast	**0.011**	**0.020**	**0.014**	**0.012**	**0.026**	**0.076**	**0.031**
CI:25%	0.008	0.012	0.011	0.006	0.021	0.034	0.016
CI:10%	0.006	0.008	0.008	0.003	0.016	0.016	0.009
CI:5%	0.006	0.006	0.007	0.002	0.014	0.010	0.006
CI:1%	0.004	0.004	0.005	0.001	0.010	0.004	0.003

Table 10. Forecast of p_{inside} in 2001 for Strait of Georgia hatchery indicators using the salinity model[†].

Parameter	
a	-28.9
b	1.002
N	23
Confidence Intervals:	
1% lower	0.330
5% lower	0.446
10% lower	0.507
25% lower	0.602
Forecast	**0.698**
75% lower	0.779
90% lower	0.838
95% lower	0.869
99% lower	0.916

[†] The fitted model was $Logit(p_{inside}) = bS + a$ where *S* is the average February surface salinity at Chrome and Sisters islands in the return year.

Table 11. Estimates of coho abundance in the Strait of Georgia + Fraser aggregate ("StG-Fr") and in the west Vancouver Island aggregate ("wVI"). WVI abundance estimates are shown using the hatchery escapement (RCH) and the proxy for hatchery escapements (SF85, see text).

Return Year	StG-Fr (1,000's)	wVI (1,000's) RCH	SF85
1984	2,400	660	-
1985	1,500	-	-
1986	2,000	610	590
1987	1,800	1,300	1,130
1988	2,400	620	710
1989	1,300	600	710
1990	2,100	980	1,410
1991	1,600	550	610
1992	2,000	510	660
1993	1,900	320	366
1994	1,400	460	1,300
1995	1,300	500	1,100
1996	800	380	570
1997	320	180	310
1998	360	450	880
1999	330	260	580
2000	560	920	1,150

Table 12. Forecast and observed abundance for west Vancouver Island (wVI) and Strait of Georgia + Fraser (StG-Fr) aggregates in 2000.

	StG-Fr	wVI
Observed 2000	**5.6E+05**	**9.2E+05**
Model used	RAT3	3YRA
CI:1%	7.4E+04	8.7E+04
CI:5%	1.1E+05	1.3E+05
CI:10%	1.4E+05	1.5E+05
CI:25%	1.8E+05	2.0E+05
Forecast 2000	**2.5E+05**	**2.7E+05**
CI:75%	3.4E+05	3.7E+05
CI:90%	4.5E+05	4.9E+05
CI:95%	5.5E+05	5.9E+05
CI:99%	8.3E+05	9.0E+05

Table 13. Forecasts of abundance for StG-Fr and wVI aggregates in 2001, with confidence limits. The recommended models are shaded.

	StG-Fr aggregate abundance				wVI aggregate abundunce			
	LLY	3YRA	RAT1	RAT3	LLY	3YRA	RAT1	RAT3
CI:1%[†]	2.1E+05	1.2E+05	2.0E+05	1.8E+05	1.8E+05	1.1E+05	1.3E+05	1.5E+05
CI:5%	2.9E+05	1.8E+05	3.3E+05	2.8E+05	3.1E+05	1.7E+05	3.4E+05	3.5E+05
CI:10%	3.4E+05	2.2E+05	4.2E+05	3.4E+05	4.0E+05	2.2E+05	5.4E+05	5.2E+05
CI:25%	4.3E+05	3.0E+05	6.0E+05	4.7E+05	6.0E+05	3.1E+05	1.1E+06	9.7E+05
2001 forecast	**5.6E+05**	**4.0E+05**	**8.9E+05**	**6.5E+05**	**9.2E+05**	**4.6E+05**	**2.4E+06**	**1.9E+06**
CI:75%	7.3E+05	5.5E+05	1.3E+06	9.1E+05	1.4E+06	6.7E+05	5.0E+06	3.6E+06
CI:90%	9.4E+05	7.3E+05	1.9E+06	1.2E+06	2.1E+06	9.6E+05	1.0E+07	6.7E+06
CI:95%	1.1E+06	8.9E+05	2.4E+06	1.5E+06	2.7E+06	1.2E+06	1.6E+07	1.0E+07
CI:99%	1.5E+06	1.3E+06	4.0E+06	2.4E+06	4.7E+06	2.0E+06	4.2E+07	2.4E+07

[†] The stated % of observations will be less than tabulated value.

Table 14. 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*	20039	18313	89089	26400
	MAD	13162	13600	36771	19022
	n	25	23	24	22
North Thompson	*RMSE*	81063	67035	195205	117076
	MAD	61265	52690	136951	83540
	n	25	23	24	22
Lower Thompson	*RMSE*	19519	16592	52059	32372
	MAD	10478	9370	21143	15740
	n	16	14	15	13
Total Thompson	*RMSE*	107554	77169	259448	117629
	MAD	82603	64405	179287	85698
	n	16	14	15	13
Fraser/non-Thompson	*RMSE*	2228	NA	469	NA
	MAD	2106	NA	469	NA
	n	2	0	1	0
Total Interior Fraser	*RMSE*	2592	NA	1070	NA
	MAD	2554	NA	1070	NA
	n	2	0	1	0

Table 15. Performance of 2000 forecasts of total abundance for the interior Fraser sub-regions and the entire interior Fraser aggregate. Note that the Fraser/lower Thompson includes lower Thompson and non-Thompson Fraser streams. All forecasts were based on the 3YRA model.

	Fraser-Lwr Thompson		South Thompson		North Thompson		Interior Fraser	
CI	Forecast	Observed	Forecast	Observed	Forecast	Observed	Forecast	Observed
99%	9.7E+04		1.9E+04		6.9E+04		1.3E+05	
95%	4.7E+04		1.1E+04		3.5E+04		7.4E+04	
90%	3.3E+04		8.4E+03		2.5E+04		5.6E+04	
75%	1.9E+04		5.4E+03		1.5E+04		3.6E+04	
50%	**1.0E+04**	**9.5E+03**	**3.4E+03**	**4.2E+03**	**8.4E+03**	**7.9E+03**	**2.2E+04**	**2.2E+04**
25%	5.6E+03		2.1E+03		4.8E+03		1.4E+04	
10%	3.2E+03		1.4E+03		2.8E+03		9.0E+03	
50%	2.2E+03		1.0E+03		2.0E+03		6.8E+03	
1%	1.1E+03		5.9E+02		1.0E+03		3.9E+03	

Table 16. Forecasts of total abundance for Thompson River watershed coho in 2001 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=14		n=23		n=23		n=14	
99%	3.3E+04	338%	2.2E+04	118%	6.0E+04	91%	8.2E+04	91%
95%	1.7E+04	177%	1.3E+04	70%	3.3E+04	50%	5.0E+04	56%
90%	1.2E+04	128%	1.0E+04	54%	2.5E+04	37%	4.0E+04	44%
75%	7.4E+03	77%	6.6E+03	36%	1.5E+04	23%	2.7E+04	30%
50%	**4.3E+03**	**44%**	**4.2E+03**	**23%**	**9.1E+03**	**14%**	**1.8E+04**	**20%**
25%	2.4E+03	25%	2.7E+03	15%	5.5E+03	8%	1.2E+04	13%
10%	1.5E+03	15%	1.8E+03	10%	3.4E+03	5%	8.1E+03	9%
50%	1.1E+03	11%	1.4E+03	8%	2.5E+03	4%	6.3E+03	7%
1%	5.6E+02	6%	8.2E+02	4%	1.4E+03	2%	3.9E+03	4%

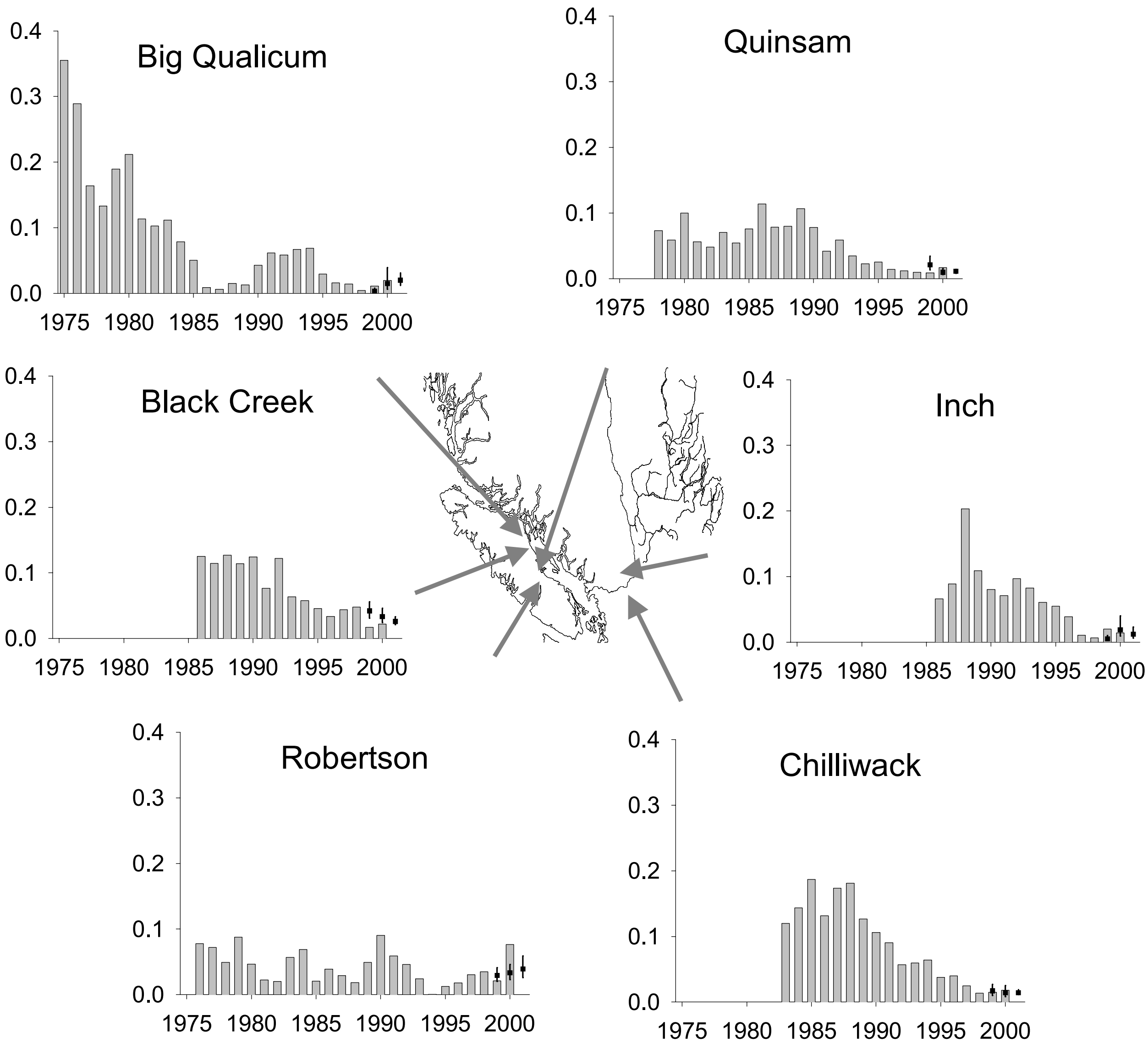


Figure 1. Marine survivals vs. return year for six coho indicators in southern British Columbia. Robertson survival is calculated only from CWT returns to the hatchery. Forecasts for 1999 to 2001 are shown with associated 50% confidence intervals.

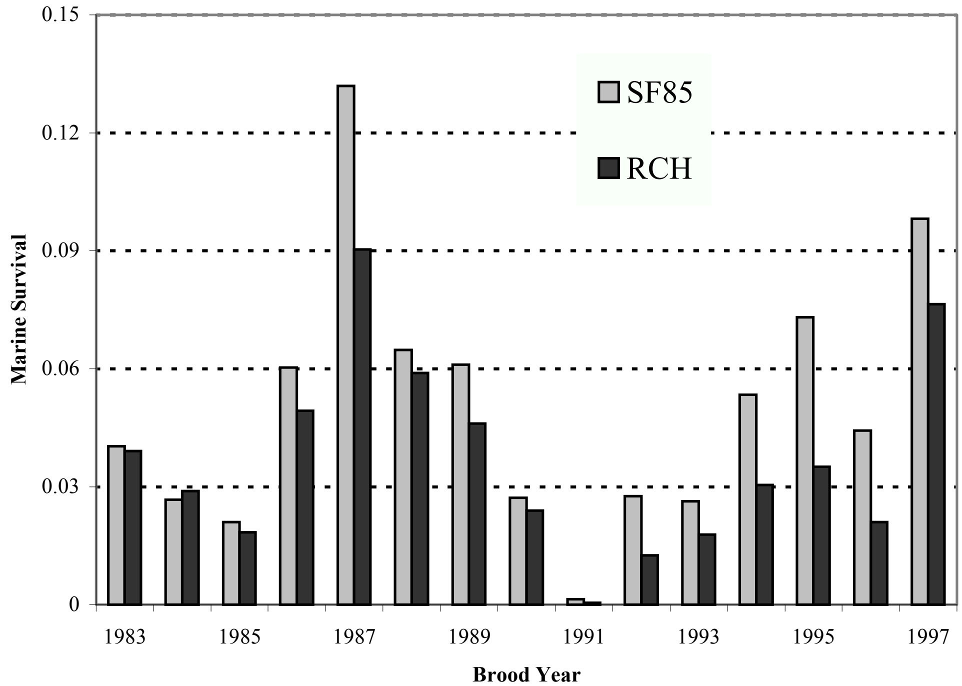
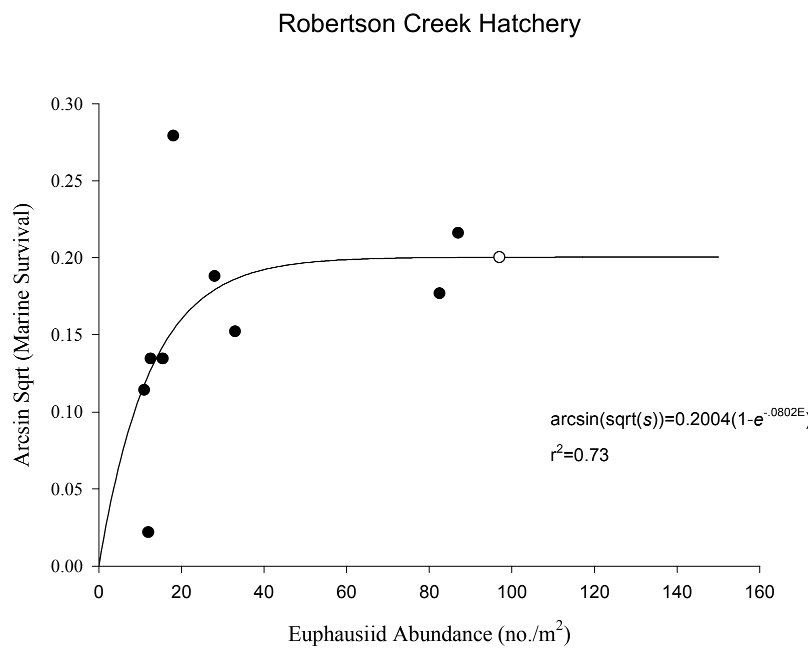


Figure 2. Survival of Robertson Creek Hatchery coho from 1986 to 2000 where survivals were calculated using escapements recorded at the hatchery (RCH) and using a hatchery escapement estimated as 85% of the Stamp Falls count of coho (SF85).



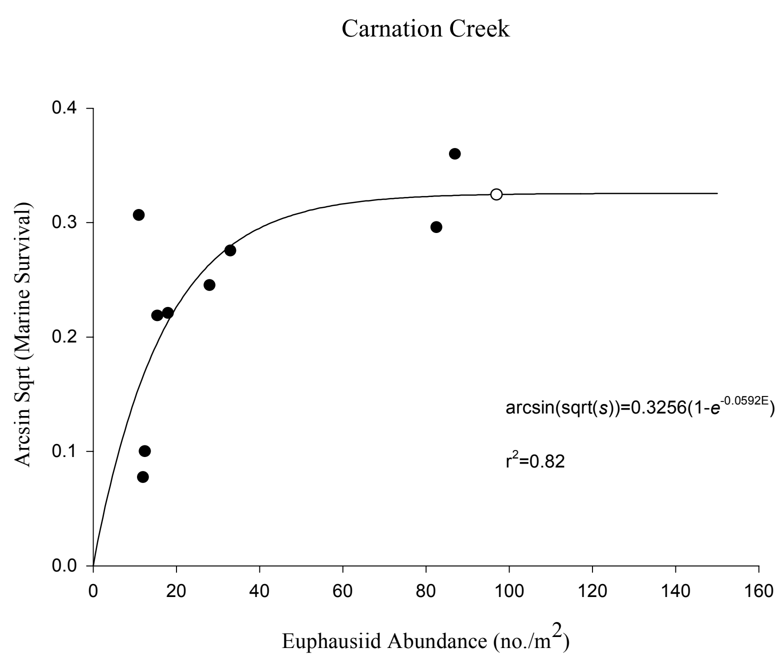


Figure 3. Marine survival at Robertson Creek Hatchery and Carnation Creek and euphausiid abundance in Barkley Sound. Marine survival rates are arcsine square root transformed and both are based on Robertson Hatchery records of escapement (see text). For reference, the y-axis values of 0.1, 0.2, 0.3, and 0.4 approximately correspond to 1%, 4%, 9% and 15% survival. The fitted curve was used to predict the marine survival of the 2001 adult return (clear circle).

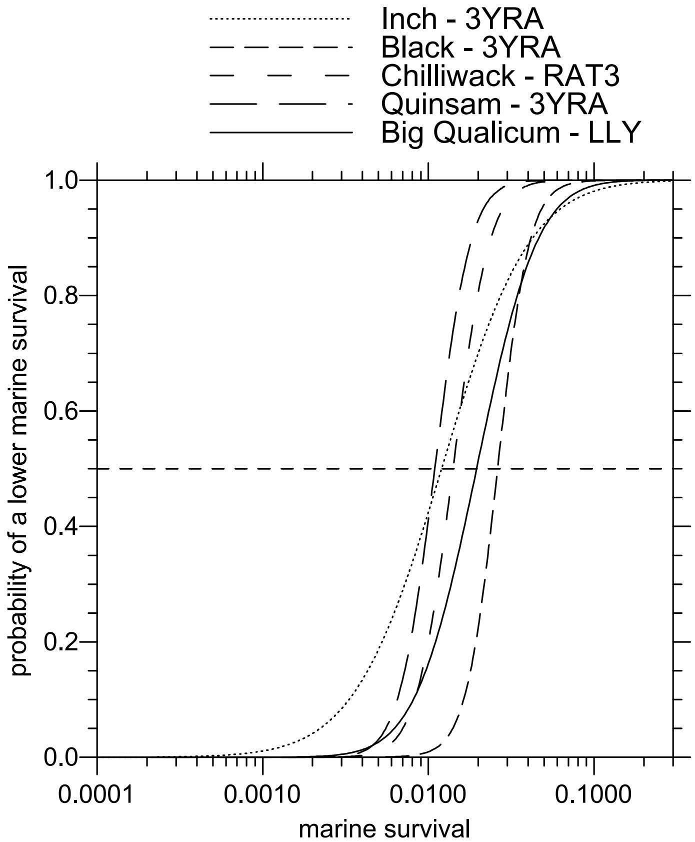


Figure 4. Confidence intervals around the time-series forecasts of marine survivals for 2001 for four hatchery indicators and Black Creek.

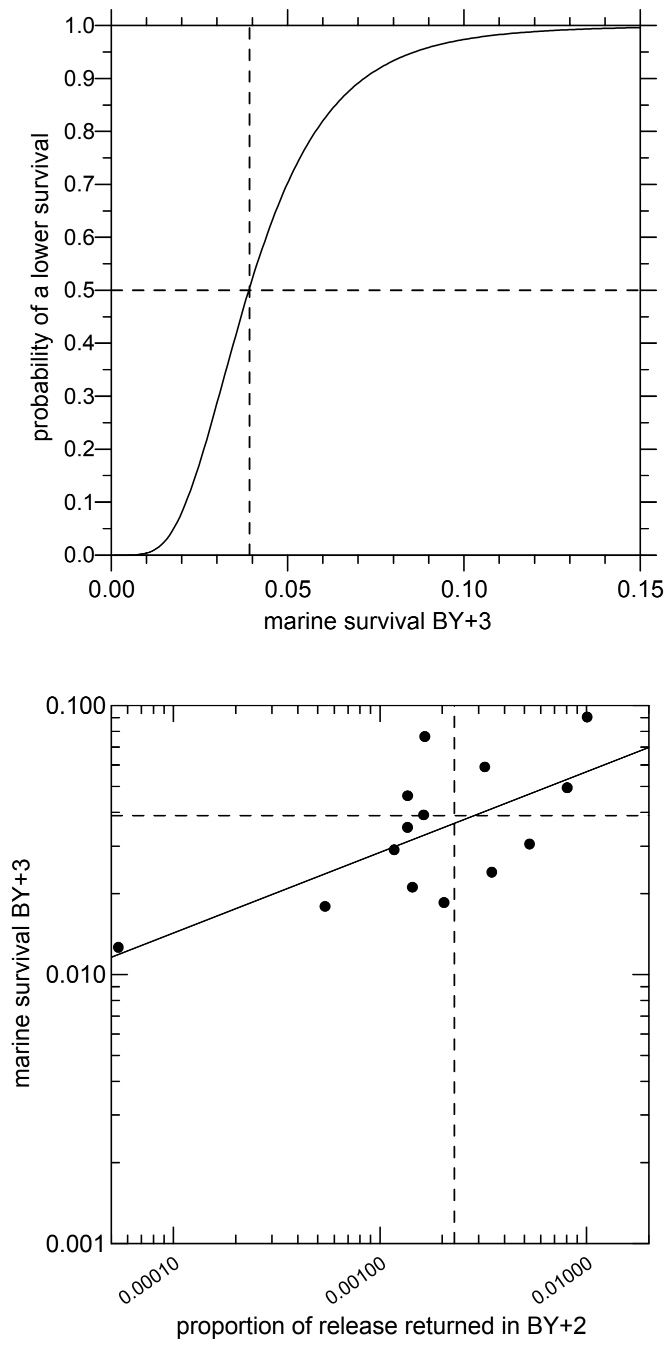


Figure 5. Return and survival forecast for Robertson Creek coho in 2001 using the sibling regression model (RCH jacks and adults). The lower panel is the sibling relationship. The upper panel is the probability distribution for marine survival of the adult return in 2001.

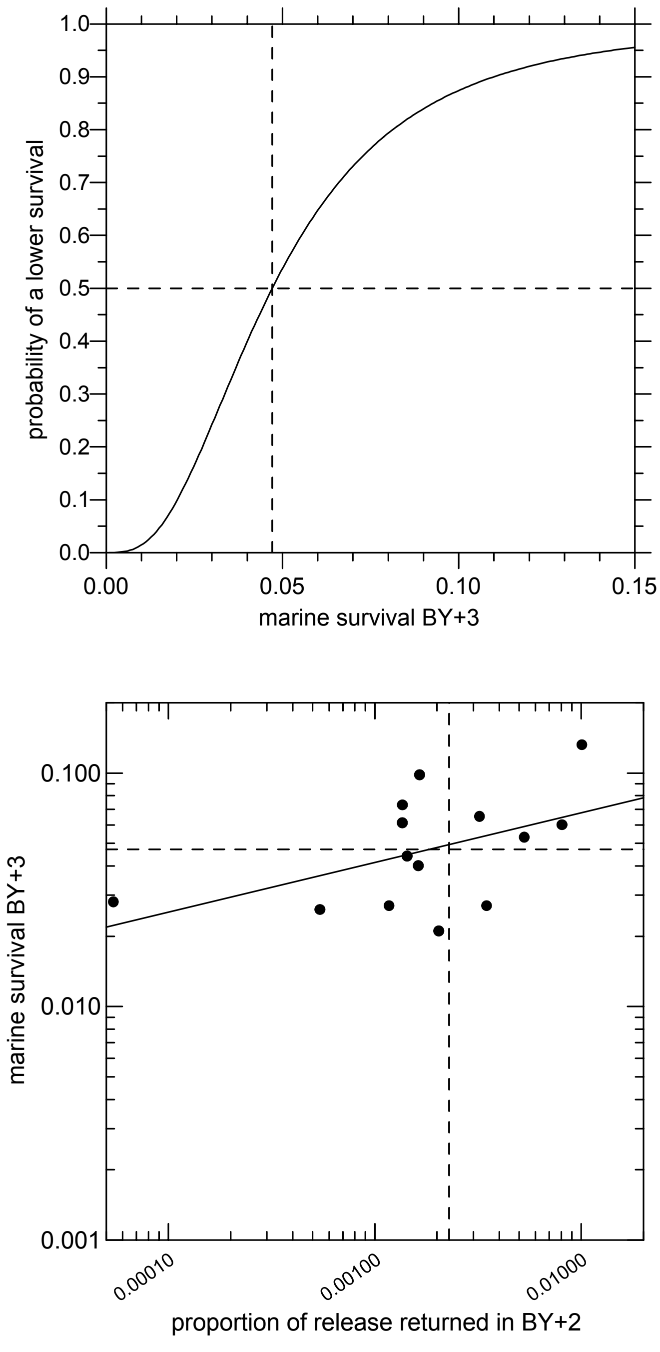


Figure 6. Return and survival forecast for Robertson Creek coho in 2001 using the sibling regression model (RCH Jacks v. SF85 return). The lower panel is the sibling relationship. The upper panel is the probability distribution for marine survival of the adult return in 2001.

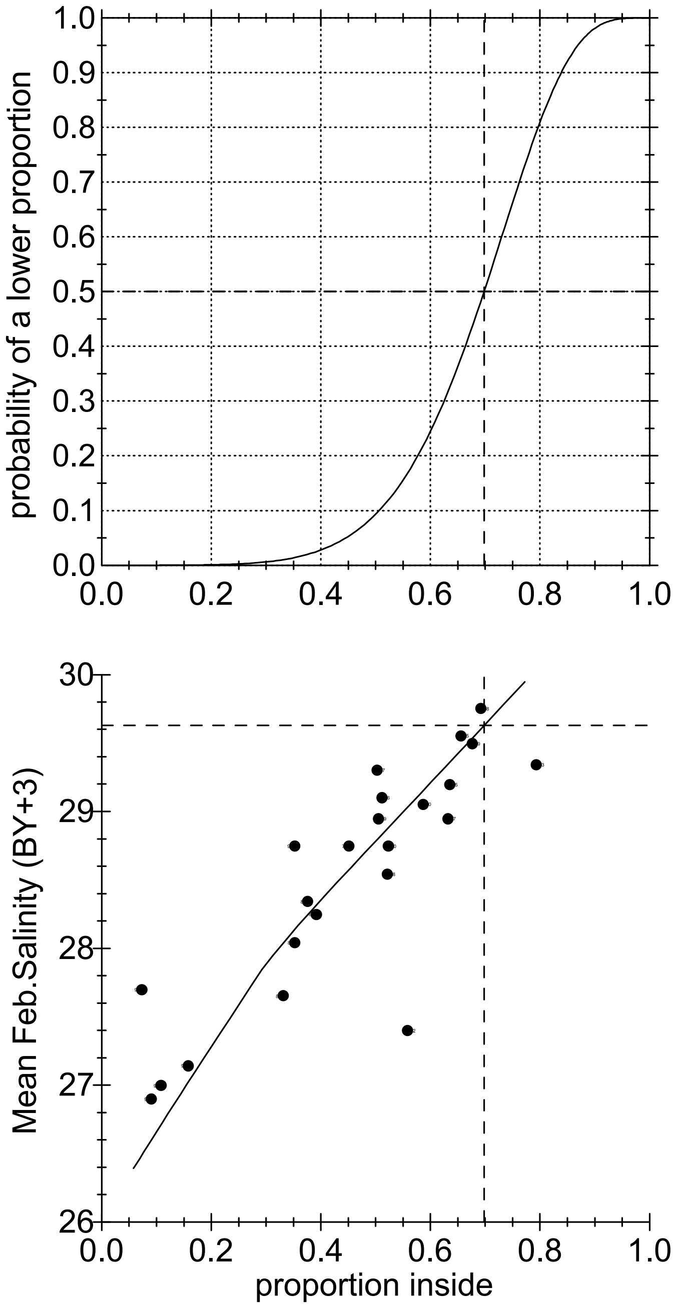


Figure 7. Predicting p_{inside} for 2001 using mean February salinity's at Chrome and Sisters islands. The lower panel is the predictive relationship. The upper panel is the probability distribution for the point predictions. A February salinity of 29.63 was used.

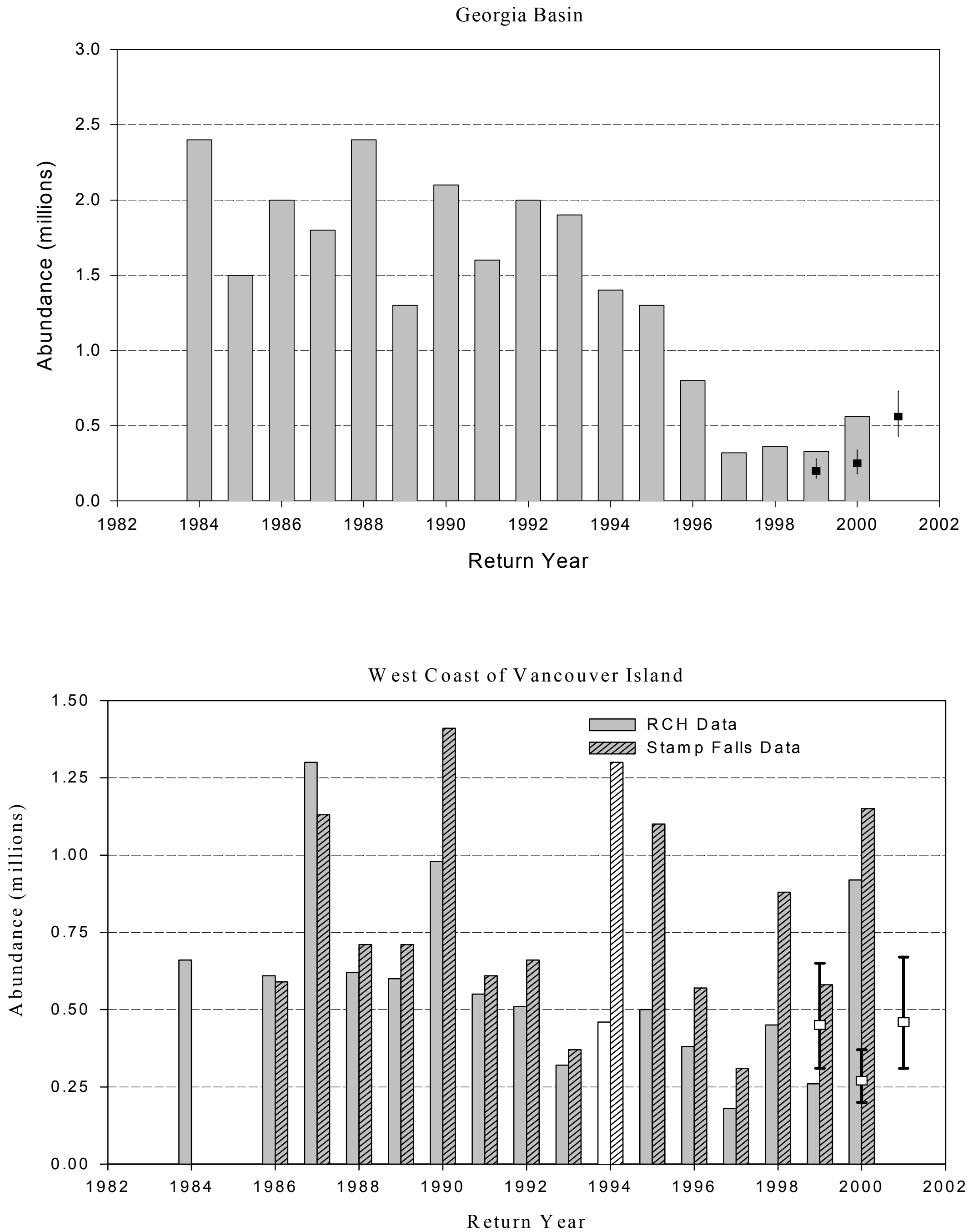
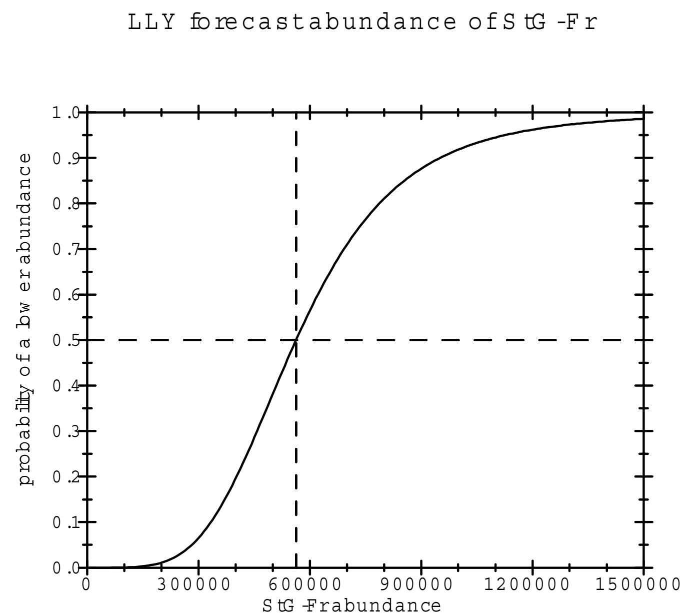


Figure 8. Abundance estimates for the Strait of Georgia+Fraser aggregate and the west coast of Vancouver Island aggregate of southern British Columbia coho. Both manners of estimating wVI abundances are shown (see text). 1994 wVI estimates are obviously wrong (escapements and catch were near zero that year) and this year was not included in time series analyses. The forecast abundances for 1999 to 2001 with associated 50% CI's are shown.



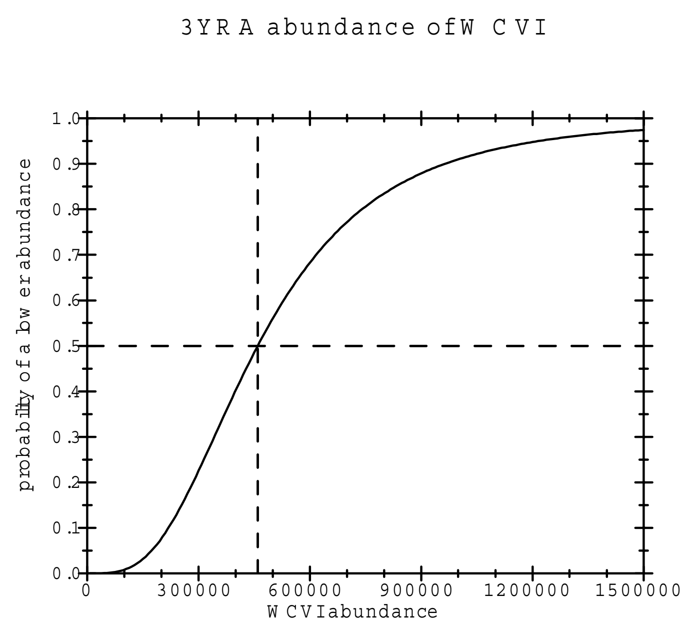


Figure 9. Probability plots for the abundance forecasts for StG-Fr and wVI aggregate abundances in 2001 using the recommended models. The wVI forecast uses the Robertson Hatchery return as measured at the hatchery (RCH data).

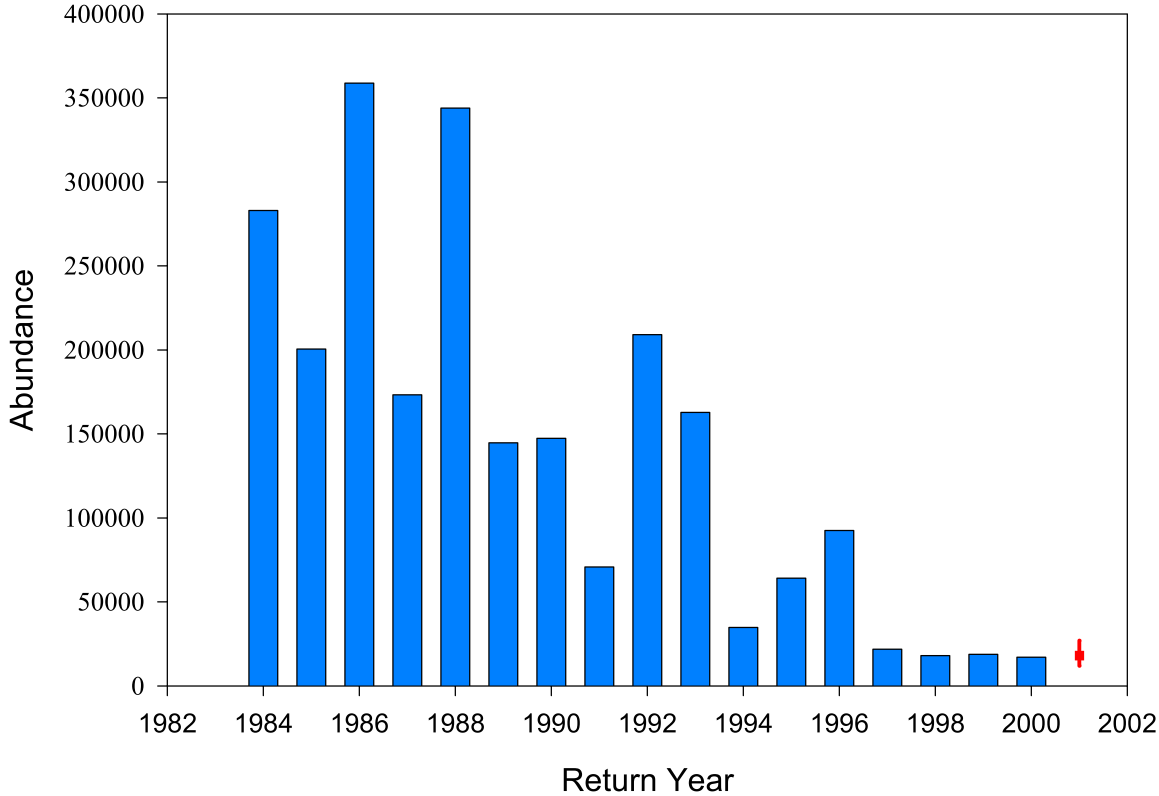


Figure 10. Estimated total abundance of Thompson River watershed coho from 1984 to 2000. The forecast for 2001 is shown with its associated 50% CI.