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Forecast for southern and central British Columbia coho salmon in 2003.

Prévisions pour le saumon coho du sud et du centre de la Colombie-Britannique en 2003.

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Abstract

This Working Paper presents 2003 forecasts of marine survival, abundance and distribution of coho in southern and central British Columbia (Areas 7 to 29: the Fraser River system and coastal waters south of approximately 53° N).

There are five hatchery and three wild coho indicator stocks in southern BC. Forecasts of survival for these stocks are:

Management Unit	Indicator	Recommended Model	Predicted Survival, 2003 (50% CI)	Change (2003 forecast minus 2002 observed S)
GBW	Big Qualicum	LLY	0.016 (0.010 - 0.027)	0%
	Quinsam	3YRA	0.014 (0.011 - 0.018)	8%
	Black (wild)	3YRA	0.043 (0.030 - 0.061)	-12%
LowFr	Chilliwack	RAT3	0.040 (0.029 - 0.055)	21%
	Inch	LLY	0.021 (0.009 - 0.047)	0%
	Salmon (wild)	LLY	0.063 (0.048 - 0.083)	0%
GBW, LowFr	All hatcheries	CPUE	0.014 (0.011 - 0.017)	-33%
SWVI, NWVI	Robertson	Sibling	0.047 (0.029 - 0.077)	0%
	Carnation (wild)	Euphausiid	0.055 (0.053 - 0.058)	8%

Survivals on the west side of the Str. of Georgia (GBW) are expected to range from 1.5% for hatcheries to 4.3% for higher productivity wild stocks. This represents little change from 2002. Survivals are also forecast to remain about the same in the lower Fraser (LowFr) area but at higher levels than on the Vancouver Island shore (6.3% for wild coho). Overall for the Georgia Basin, we characterise survivals as poor (GBW) to below average (LowFr), basing this qualitative assessment on previously higher survivals and on calculations of the survivals needed to sustain stocks of low to average productivity. CPUE data also indicate low survivals, less than last year. There is little data for the east side of the strait but other information suggests survivals are no better than in GBW.

We forecast that an average proportion of coho that originated in the Georgia Basin will rear in the Strait of Georgia in the spring and summer before spawning. Although not a prediction of a strong 'inside' year, the proportion is expected to be more 'inside' than in 2002 and the mean of the last 10 years.

On the west coast of Vancouver Island (wVI), survival of wild coho is forecast to be 5.5%, which is similar to the Georgia Basin survivals. Survival of Robertson Hatchery coho is forecast to be more than Georgia Basin hatcheries, as it has been for many years. These forecasts are similar to survivals in 2002. Both indicators are in SW Vancouver Island but results are also applied to NW Vancouver Island, which lacks indicators.

The abundance of Thompson River coho is expected to be 35,700. This is significantly less than the 51,000 in 2002 but more than the brood year abundance of 15,800. Returns in 2001 and 2002 also exceeded their brood year returns. This stock aggregate is slowly recovering.

The abundance forecasts for central British Columbia remain the only method of forecasting for this area. Forecasting methods conform to those of past forecasts in this area. The forecasts of total abundance and escapement for the five Central Coast aggregates are given in the following table. Note that the abundance of coho in Area 13 (Johnstone Strait) is expected to be very poor:

Area	Recommended Model	Return (Abundance) Forecast P[1]	Return (Abundance) Characterization	Escapement Forecast P[1]	Escapement Characterization	Escapement % of S_{max}[2]
7	3YRA	28%	Below Average	58%	Average	38%
8	3YRA	15%	Below Average	40%	Average	43%
9 - 11	3YRA	38%	Average	91%	Well Above Average	129%
12	3YRA	13%	Well Below Average	48%	Average	27%
13	3YRA	2%	Well Below Average	19%	Below Average	6%

[1] Proportions of observed abundances from 1950 to 2002 that are less than the 2003 forecast.

[2] The escapement that on average produces the maximum recruitment, as determined from the S-R analysis.

Résumé

Ce document de travail présente les prévisions de survie en mer, d'abondance et de répartition du saumon coho du sud et du centre de la Colombie-Britannique (zones 7 à 29 : le réseau fluvial du Fraser et les eaux côtières situées au sud d'environ 53° N).

Voici les prévisions de la survie pour les huit stocks indicateurs (cinq stocks d'écloserie et trois stocks sauvages) du sud de la C.-B :

Unité de gestion	Indicateur	Modèle recommandé	Taux de survie prévu en 2003 (I.C. à 50 %)	Changement (S prévue 2003 moins S observée en 2002
BGO	Big Qualicum	LLY	0,016 (0,010 - 0,027)	0 %
	Quinsam	3YRA	0,014 (0,011 - 0,018)	8 %
	Black (sauvage)	3YRA	0,043 (0,030 - 0,061)	-12 %
BasFr	Chilliwack	RAT3	0,040 (0,029 - 0,055)	21 %
	Inch	LLY	0,021 (0,009 - 0,047)	0 %
	Salmon (sauvage)	LLY	0,063 (0,048 - 0,083)	0 %
BGO, BasFr	Toutes les écloseries	CPUE	0,014 (0,011 - 0,017)	-33 %
SOIV, NOIV	Robertson	Germains	0,047 (0,029 - 0,077)	0 %
	Carnation (sauvage)	Euphausiacés	0,055 (0,053 - 0,058)	8 %

Nous prévoyons que les taux de survie dans la partie ouest du détroit Georgia (BGO) varieront de 1,5 % pour les stocks d'écloserie à 4,3 % pour les stocks sauvages plus productifs. Ces taux sont semblables à ceux de 2002. Les taux de survie devraient aussi rester à peu près les mêmes dans la région du bas Fraser (BasFr), mais à des niveaux plus élevés que ceux de la côte de l'île de Vancouver (6,3 % pour le saumon coho sauvage). Globalement, nous caractérisons les taux de survie comme faible (BGO) à inférieurs à la moyenne (BasFr). Cette évaluation qualitative est fondée sur les taux de survie plus élevés auparavant et sur des calculs des taux nécessaires pour soutenir des stocks de productivité faible à moyenne. Les données de CPUE indiquent également de faibles taux de survie, inférieurs à ceux de l'an dernier. Nous disposons de peu de données pour la partie est du détroit, mais d'autres indications portent à croire que la survie n'y est pas meilleure que dans le BGO.

Nous prévoyons qu'une proportion moyenne des cohos provenant du bassin de Georgia passeront le printemps et l'été dans le détroit de Georgia avant de frayer. Bien que nous ne prévoyions pas une forte année « intérieure », la proportion devrait être plus « intérieure » qu'en 2002 et que la moyenne pour les dix dernières années.

Sur la côte ouest de l'île de Vancouver Island (OIV), nous prévoyons que le taux de survie du coho sauvage sera de 5,5 %, une valeur semblable aux taux pour le bassin de Georgia. Le saumon coho de l'écloserie Robertson devrait présenter un taux de survie plus élevé que ceux des écloseries du bassin de Georgia, comme c'est le cas depuis plusieurs années. Ces prévisions sont semblables aux taux de survie de 2002. Les deux stocks indicateurs sont situés dans le sud-ouest de l'île de Vancouver, mais les résultats sont aussi appliqués au nord-ouest de l'île où il n'y a pas de stocks indicateurs.

L'abondance du saumon coho de la rivière Thompson devrait se chiffrer à 35 700 individus, soit significativement moins que l'abondance de 2002 (51 000), mais plus que l'abondance de 15 800 observée lors de leur année d'éclosion. En 2001 et en 2002, les remontes ont également dépassé les remontes pour leur année d'éclosion respective. Ce stock combiné se rétablit lentement.

Les prévisions d'abondance pour le centre de la Colombie-Britannique constituent toujours la seule méthode de prévision pour cette région. Les méthodes de prévision correspondent à celles utilisées pour les prévisions passées dans

cette région. Le tableau suivant présente les prévisions de l'abondance totale et de l'échappée pour les cinq stocks combinés de la côte centrale. Nous prévoyons que l'abondance du saumon coho dans la zone 13 (détroit de Johnstone) sera très faible.

		Remonte (Abondance)		Échappée		
Zone	Modèle recommandé	Prévision P[1]	Caractérisation	Prévision P[1]	Caractérisation	% de S_{max}[2]
7	3YRA	28%	Inférieure à la moyenne	58 %	Moyenne	38 %
8	3YRA	15%	Inférieure à la moyenne	40 %	Moyenne	43 %
9 - 11	3YRA	38%	Moyenne	91 %	Bien supérieure à la moyenne	129 %
12	3YRA	13%	Bien inférieure à la moyenne	48 %	Moyenne	27 %
13	3YRA	2%	Bien inférieure à la moyenne	19 %	Inférieure à la moyenne	6 %

[1] Proportions des abondances observées de 1950 à 2002 qui sont inférieures à la prévision de 2003.

[2] L'échappée qui, en moyenne, donne le recrutement maximal selon l'analyse géniteurs-recrutement.

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1. Introduction

This Working Paper presents 2003 forecasts of the survival, ocean distribution and adult abundance of coho in southern British Columbia (sBC, Areas 14 to 29) and the Central Coast (CC, Areas 7 to 13). The methods we used in developing the forecasts of survival and ocean distribution are similar to those used in the previous forecast (Simpson et al. 2002)[1]. Forecasts before 2002 are: Simpson et al. (2001a), Holtby et al. (1999a, 2000), Kadowaki and Holtby (1998), Kadowaki (1997) and Kadowaki et al. (1996). This year we forecast returns per spawner of Thompson coho using time series analyses and multiplied the forecast returns per spawner by the estimated escapement in 2000 to produce a total return (abundance) forecast. We previously forecast abundance directly, using time series analyses of past returns. We also present that forecast, which weights the brood year the same as other years, and compare each method's retrospective performance. A second addition is a forecast of the abundance of coho in the Central Coast (comprising northern CC, Areas 7 to 11, and Johnstone and Queen Charlotte straits or JST, Areas 12 and 13). Forecasts for these Management Units (MU's) were included in forecasts of north coast coho in 2002 (Holtby et al. 2002). The forecast method was the same this year, although different exploitations were used for Areas 12 and 13. Finally, the Lower Fraser (LowFr) wild coho indicator at Salmon R. (Langley) has been added for the first time.

This forecast will refer to several other MU's south and east of the Central Coast:

Johnstone Strait/Mainland Inlets (JST): Johnstone Str., Queen Charlotte Str., and adjacent inlets (Areas 11, 12 and northern portion of 13)

Georgia Basin – East (GBE): east side of the Str. of Georgia, excluding the Fraser R. system (Areas 15, 16 and 28)

Lower Fraser (LowFr): Fraser R. delta and lower Fraser R. system as far upstream as Hell's Gate (Area 29)

Interior Fraser (IntFr): upstream from Hell's Gate, including the Thompson R. system (Area 29)

Georgia Basin – West (GBW): west side of the Str. of Georgia (Areas 13 (southern portion), 14, 18 and 19)

South-west Vancouver Island (SWVI): Victoria to Estevan Pt. (Areas 20-24)

North-west Vancouver Island (NWVI): Estevan Pt. to Cape Scott (Areas 25-27)

Underlined titles, above, indicate MU's that are part of the Abundance Based Management system under the Pacific Salmon Treaty.

[1] Survival is defined here as spawners per smolt, sometimes referred to as 'marine' survival, although it includes parts of the freshwater migratory phases of smolts and adults.

2. Data Sources and Treatments

2.1 Estimates of Marine Fishing Mortality

Marine fisheries for coho in sBC have been limited since 1998 in order to conserve weak stocks of concern, primarily those originating from the Thompson River. There were no commercial fisheries either directed at coho or allowing retention of coho in the Strait of Georgia and wVI in 2002. However, there were sport fisheries allowing retention of hatchery marked coho in certain areas and times. Hatchery marked coho had their adipose fin removed at the hatchery ('Ad-clips'). One unmarked coho was allowed in a daily limit of two in June and July in some inshore waters off the west coast of Vancouver Island (wVI). After July, retention of two marked coho was generally allowed in all south coast waters. There were two exceptions: unmarked retention was allowed after July in Alberni Canal (daily limit of four, one of which could be unmarked) and Port San Juan (daily limit of two coho regardless of mark status, which increased to four after September). The largest changes to fisheries regulations from 2001 to 2002 were: (1) allowing daily retention of two marked coho throughout Johnstone Str. and the Str. of Georgia (an expansion of the mark-only fishery in Areas 13 and 14 in 2001); and (2) allowing retention of marked coho in Juan de Fuca Str. after August 1st instead of mid September.

Coded wire tag (CWT) recoveries decreased when widespread coho non-retention regulations began in 1998, making CWT-based estimates of fishing mortality unreliable. The mortality of coho that were caught and released becomes relatively more important. But there are problems associated with accurately estimating encounter rates and drop-off and release mortality as well as estimating the stock composition of encounters. Selective mark-only fisheries further complicate the situation (Pacific Salmon Commission 2002). From 1998 to 2000, post-season estimates of total mortality of Thompson coho were derived from estimating the stock composition of encounters through genetic analysis of sampled coho encountered in various fisheries (Irvine et al. 2001). We estimated 2001 fishing mortality using an approach that relies on historical estimates of CWT recoveries and effort.

2.1.1 Marine fisheries, excluding Area 23 (Barkley Sound and Alberni Canal)

We have assumed that marine fishing mortality did not change in 2002 from the estimates made for 2001 in all fisheries other than the terminal Area 23 sport fishery, where we used current creel data to estimate mortality. The rest of this section details how those 2001 estimates were derived.

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

2.1.1.1 Commercial fisheries

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

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

Eqn. 1

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

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

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

Eqn. 2

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

2.1.1.2 Recreational fisheries

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

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

Eqn. 3

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

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

Eqn. 4

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

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

Eqn. 5

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

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

Eqn. 6

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

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

Eqn. 7

Table 1 shows estimates of marine exploitation rates of sBC and IntFr indicator stocks in 2001, which we are also assuming for 2002. Note that these are displayed as point estimates and therefore do not reflect the range of uncertainty in the data. Catches of marked coho and releases of unmarked coho in the Strait of Georgia were 63% and 78% less, respectively, in 2002 despite expansion of the selective mark fishery. However, marked catch and unmarked releases were 10 times greater than 2001 in Juan de Fuca Strait. On balance, coho encounters in the two straits were 24% less in 2002 (pers. comm., D. Nagtegaal, DFO, 3225 Stephenson Pt. Rd., Nanaimo). Creel data for wVI were largely limited to Area 23 in 2002 and were used below in deriving a 2002 estimate. Encounters were also less there. If we had corrected for the change in encounters from 2001 to 2002, mortality estimates would have decreased. Our uncorrected mortalities in non-terminal fisheries may therefore be over-estimates and survivals may be slightly over-estimated. However, we expect measurement errors to be large relative to these low mortality estimates and this is our justification for not modifying the estimates for 2002 (other than Robertson Hatchery mortality, which incorporates a 2002 estimate of Area 23 sport mortality, see below). For example, decreasing fishing mortality estimates by 25% would have a negligible effect on the resultant survival estimates because escapements greatly exceed fishing mortalities.

2.1.2 Area 23 (Barkley Sound and Alberni Canal)

The catch and release mortality of Robertson Hatchery coho in the directed Area 23 sport fishery in 2002 was calculated from creel data provided by K. Hein (Salmon Stock Assessment, South Coast Area, Nanaimo). This was done by assuming that all encounters of marked and tagged coho in the Area 23 sport fishery were Robertson-origin coho. Although obviously wrong, the over-estimate is probably very small based on historic recoveries from this fishery of CWT-ad coho (coho tagged with CWT's and marked with an adipose fin clip). Some marked coho were released in the fishery. The ratio of CWT-ad coho to the total number of adipose clipped coho in the Robertson escapement was used to estimate how many of these marked coho releases had tags and a release mortality of 10% was applied to that CWT-ad release estimate. Mortalities in other fisheries were calculated as explained above. The estimate of mortalities of CWT-ad coho in the Area 23 sport fishery equated to an exploitation of 7% in 2002, compared to 19.3% in 2001.

An exploitation of 3% was assumed for Carnation coho in 2002 (cf. 5% in 2001). Retention of one unmarked coho per day was allowed for part of the season in Area 23 but a large proportion of the effort was in Alberni Canal, east of Carnation Creek (Carnation Creek is near Bamfield). This effort was largely directed toward Robertson Hatchery coho (the daily limit was four coho, one of which could be unmarked). The exploitation of unmarked Robertson Hatchery coho was about 3%, based on an analysis of that hatchery's tagged but unmarked (CWT-only) release group (cf. 7.1% in 2001). This analysis included an allowance of 10% mortality of released fish. Although much of the effort was 'inside' of Carnation, we chose not to vary such a low exploitation of unmarked Robertson coho to make an estimate for Carnation coho.

2.2 Interior Fraser, Including the Thompson River

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

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

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

The time series of exploitation rates for the Thompson were generated from the Mark Recovery Program (MRP) CWT recoveries for a variety of releases from 1986 to 1997 and the escapement estimates. Estimates prior to 1986 were the arithmetic average of measured values from 1986 to 1996. Regulatory changes to salmon fisheries, beginning in 1998, saw most fisheries become non-retention for coho. Therefore, few coho were sampled for CWT's from which exploitation could be estimated. Alternatively, exploitation rates for 1998 through 2000 were estimated through the application of stock composition estimates developed from a DNA-based approach to estimates of coho killed in fisheries (Irvine et al. 2000). Using this method, the Canadian exploitation of Thompson coho is estimated to have been 1.1%. Using the effort adjustment to historic exploitation rate approach, described above, the estimate is 2.1%. Assuming the exploitation of Thompson coho in the US (excluding Alaska) in 2002 was equal to a scaled historic average of 5.9%, the DNA and effort estimates of total exploitation are 7.1% and 8.0%, respectively. We calculated the abundance of Thompson coho in 2002 using the 7.1% estimate (Table 1 and Table 3).

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

Five hatchery stocks are used in forecasting survival of south coast coho: Robertson (SWVI and NWVI), Quinsam and Big Qualicum (GBW), and Inch and Chilliwack (LowFr). Three wild stocks are used: Salmon (LowFr), Black (GBW) and Carnation (SWVI and NWVI). This is the first forecast that includes the Salmon R. indicator.

Hatchery survival rate estimates are made only for CWT-ad coho. Hatchery releases of coded wire tagged smolts have also included unmarked (CWT-only) groups since 1997. Virtually all the rest of hatchery production was marked with a pelvic fin clip in 1997 (except at Quinsam and Robertson hatcheries) and with an adipose clip since then (Simpson et al. 2001b). This mass marking was to prepare for selective mark fisheries. Smolts captured at the Salmon, Black and Carnation creek fences are tagged (only starting in 2001 at Carnation). We stopped fin clipping the Salmon River and Black Creek runs in 1998 in preparation for selective mark fisheries. Carnation Creek coho are not marked either.

We used the hatchery releases of CWT-ad smolts that are recorded in the MRP database maintained at the Pacific Biological Station in Nanaimo, BC. Hatchery escapements for last year were provided by the Habitat and Enhancement Branch (pers. comm. R. Gransden, Vancouver; G. Bonnell, South Coast Area, Victoria). These are preliminary estimates: escapement data for years before last year are final/near-final estimates as entered in the MRP database. The differences between preliminary and final estimates are usually small. Smolt release and escapement data for Black Cr. are collected by us (KS) and Carnation Cr. data are provided by the BC Ministry of Forests (pers. comm. P. Tschaplinski, Victoria). Catch and release data for the freshwater sport fisheries in Somass R. (Robertson Hatchery) were provided by J. Patterson (DFO, S. Coast Area, Nanaimo). S. Stenhouse (DFO, S. Coast Area, Nanaimo) provided the same for Big Qualicum R. and S. Grant (DFO, Lower Fraser Area, Delta) provided creel data for Nicomen Slough (Inch Hatchery) and Chilliwack/Vedder River.

Data for each indicator are shown in Table 4. All years were queried in MRP using only those codes approved for survival analysis. This more extensive use of the survival analysis criterion resulted in many differences from the data presented in previous forecast documents. However, only a few differences are large. Chilliwack returns are an exception. No Chilliwack releases prior to the 1996 brood year are approved for survival analysis because fishing mortality was insufficiently known for the large Chilliwack/Vedder sport fishery and HEB have some concerns regarding hatchery recovery procedures in some earlier years (pers. comm., R. Cook, HEB, Vancouver). We and earlier authors chose to use the production and monitoring releases from pre-1996 broods anyway. Jack and adult returns from each indicator are the sum of estimated recoveries in all catch regions, including Alaska and Washington.

2.4 Central Coast

Escapement data for central coastal British Columbia were obtained from stock assessment staff in Campbell River (pers. comm. P. Zetterberg, DFO, Campbell River) and Bella Coola (pers. comm. M. Mortimer, DFO, Bella Coola). All data from 2002 should be considered preliminary and subject to revision as escapement estimates are finalized.

Some exploitation rate data for Toboggan Creek (for northern Central Coast areas 7-11) were obtained from stock assessment staff in the Prince Rupert Office (pers. comm. J. Sawada, DFO, Prince Rupert).

2.5 Salinity Data

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

3. Methods - Forecasting Models and Retrospective Analysis of Predictive Power

3.1 Forecasting Models

3.1.1 Time Series

In this document, we forecast some of the following in different parts of the forecast area: catch distribution (p_{inside}), marine survival (s), abundance (A) and returns per spawner (RS). Survivals and abundances are forecast in more than one way. One method uses four quasi-time series models. In each model the variable being forecast (v_t) is first transformed:

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

The Log transformation was used for abundance and returns per spawner of Thompson coho and abundance of CC coho. The Logit transformation was applied to all survival data and it was also used to transform p_{inside} values in its predictive regression with salinities.[2] The four time series models are:

Mnemonic	Model	Equation
LLY ("Like Last Year")	$Z_{t+1} = Z_t + e_t$	Eqn. 9
3YRA (3-year average)	$Z_{t+1} = \frac{\sum_{k=t-2,t} Z_k}{3} + e_t$	Eqn. 10
RAT1 (1 year trend)	$Z_{t+1} = \frac{Z_t^2}{Z_{t-1}} + e_t$	Eqn. 11
RAT3 (average 3-year trend)	$Z_{t+1} = \frac{\sum_{k=t-2,t} \left(Z_k / Z_{k-1} \right)}{3} Z_t + e_t$	Eqn. 12

[2] The Logit transformation, $Z_t = ln\left(\frac{u_t}{1-u_t}\right)$, stabilizes variances and puts survival and 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.

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

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

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

3.1.2 Abundance Forecasts for Central Coast

Estimates of escapement to individual streams throughout BC have been made since at least 1950. These estimates are mostly based on visual inspections of the streams. The methods used to inspect the streams, and convert the counts to estimates of escapement, the frequency of surveys, etc., are largely undocumented. These methods are known to differ between systems and to have changed over time. The records are also fragmentary. Nevertheless we think that the time series do contain information about escapement trends in each area.

To extract that information we first coded the various designators for "no-data" to a common missing value indicator. We then took out streams that have had a significant hatchery contribution. We then scaled the escapement (E) in each stream i to the maximum escapement recorded in that stream across all years t:

$$p_{i,t} = \frac{E_{i,t}}{max\left(E_i\right)} \qquad \text{Eqn. 13}$$

Then the $p_{i,t}$ were averaged across all streams *i* within each year *t* to give a time series (p_{max}) for the area as a whole. The "average-stream" or index escapement was constructed by multiplying p_{max} by the average across the *i* streams of max (E_i). This procedure was carried out for streams aggregated by Statistical Area with the exception of Areas 9 to 11, which were grouped together.

To construct an index of total abundance we then made some assumptions about the time series of historical exploitation rates. We know from CWT recoveries in ocean fisheries between 1987 and 1994 that coho from the entire North Coast (Areas 1 to 6) and northern Central Coast (Areas 7-8) have similar ocean distributions (Anon. 1994). Most coded-wire tags have been recovered in troll fisheries both in Alaska and northern BC. This lead us to assume that the levels and the temporal patterns in ocean exploitation rates are likely similar between all of the sites in the North Coast and northern Central Coast. We have no CWT data from stocks in Areas 9 to 11, so for the purposes of this forecast we assumed that the ocean distribution would be similar to Areas 7 and 8. The exploitation rates used for the Johnstone Strait management areas 12 & 13 were derived from three northern Strait of Georgia CWT indicator stocks: Quinsam (hatchery), Big Qualicum (hatchery), and Black Creek (wild).

Forecasts for the average-stream indices were made in two ways. First, total returns to the "average stream" within each aggregate were forecast using the four time-series models. Second, the time series of escapement and returns were used as inputs to Ricker stock-recruitment analyses, which were then used to forecast recruitment and returns in 2003 using observed spawner indices in 2000.

The 'average-stream' indices may be effective descriptors of status of coho within a geographical area. Some re-grouping might be advisable to combine streams of similar physiography. However, the utility of the average-stream index in describing trends within an area have not been thoroughly explored and no diagnostics have been developed for recognizing situations where the index is unsuitable.

To give the reader a feel for the approximate likelihood of forecast values, the forecasts have been expressed in terms of Z-scores:

$$Z = \frac{x - \bar{x}}{SD} \qquad \text{Eqn. 14}$$

Tabulated values of Z and their associated cumulative probability values can be found in most statistical texts but for convenience we have graphed the cumulative probability values for Z±3 (Figure 1).

3.1.3 Sibling Survival Forecasts for Strait of Georgia and wVI

Marine survival rates were also predicted using a sibling-regression model, where the total return of adult (age x.1) coho in year $t+1$ was regressed on the estimated escapement of jacks (age x.0) the previous year:

$$ln\,R_{t+1,x.1} = b\,ln\,E_{t,x.0} + a \qquad \text{Eqn. 15}$$

Jack escapements were used rather than returns.[3] We do not estimate marine fishing mortality of age x.0 coho like we do age x.1 coho (Sect.2.1). There is little fishing mortality at this age and it is not normally considered in estimates of year class abundance and survival.

Predicted survival was then calculated by dividing the predicted x.1 return by the number of smolts released. Confidence limits around the forecasts were determined using linear regression analysis.

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[3] Previous forecast documents also stated that escapement was being used but, in fact, total returns were used in many years. It was an insignificant error because virtually all age x.0 recoveries are in the escapement.

3.1.4 Euphausiid - Based Survival Forecast for wVI

The euphausiid-based forecast uses the relationship presented in Simpson et al. (2002). Marine survival variation of Carnation Cr. coho can be explained by the general regression:

$$ln\ R_{t+1,x.1} = a \bullet ln\ Eu_t + b \bullet ln\ Sm_t + c \qquad \text{Eqn. 16}$$

where *Eu* is euphausiid abundance, *Sm* is number of smolts and *c* is the intercept. Euphausiid abundance (no. • m^{-2}) is for 9 – 12 mm *Thysanoessa spinifera*, the euphausiid that coho smolts consume during their first summer on the coasts of Oregon (Petersen et al. 1982) and southwest Vancouver Island (Tanasichuk, in prep.). The euphausiid data come from a zooplankton monitoring program which began in 1991.

Figure 2 shows scatter plots of the natural logarithm of number of returning adults and natural logarithms of number of out-migrating smolts and median euphausiid abundance. The plots indicated that the data for the 1994 return year did not follow the apparent trends. These data represented fish from the 1991 brood year which were exposed to high concentrations of mackerel in Barkley Sound as smolts in 1993 (Simpson et al. 1996). We decided that the data for the 1994 return year represented a highly unusual situation and consequently excluded them from the analyses.

3.1.5 CPUE Survival Forecast for Strait of Georgia

Surveys for juvenile (age x.0) salmon in the Strait of Georgia have been conducted in late June and July since 1996, aboard the CCGS *W.E. Ricker*. As noted in Beamish et al. (2000a), the survey design (Figure 3) has been constant during this time, as has the gear used: a modified mid-water trawl (approximate dimensions: 14 x 36 x 200 m) towed at 4-5 knots. The sets (10-12 per day) are performed according to a stratified random design at 15 m depth increments (i.e., head-rope at surface, 15, 30, 45 or 60 m) with 50% of the effort weighted to surface tows. Upon retrieval of the catch, the various species are sorted by experienced DFO personnel and counted. All coho are examined for presence or absence of the adipose fin (or other fin clips) as well as scanned for CWT's. Sub-samples of the catch are then processed (morphology, otoliths/scale collection, diet analysis, etc). When a positive CWT response is obtained, the head is removed, bagged with an identifying tag and stored until the tag is recovered and decoded. Net opening size, depth, speed of tow and water temperature at net depth are recorded for each set. Further references are Beamish and Folkes (1998), Beamish et al. (2000b) and Sweeting et al. (2003).

There is a summary of the annual catches of marked and unmarked coho in Table 5. We used a linear regression model to forecast coho survival for 2003, where the independent variable was catch per unit effort (CPUE) of either Ad-clipped (hatchery) coho or of all coho. The CPUE was calculated by dividing the total or Ad-clipped catch for the survey by the total number of hours fished in that survey:

$$CPUE = \sum (catch) \div (\sum (minutes\ fished)/60\ min) \qquad \text{Eqn. 17}$$

CPUE was regressed against the mean survival of the four hatchery indicator stocks (Chilliwack, Inch, Big Qualicum and Quinsam):

$$Z_{t+1,x.1} = bZ_{t,x.0} + a \qquad \text{Eqn. 18}$$

where $Z_{t+1,x.1}$ is the Logit transform of mean adult survival and $Z_{t,x.0}$ is the ln transform of CPUE of the same brood in the previous year.

3.1.6 Salinity Regressions

Coho originating in systems around the Strait of Georgia are largely caught in the Strait or on the west coast of Vancouver Island but the proportion caught in each area varies between years (Kadowaki 1997; Simpson et al. 2000). The measure of distribution we use is the proportion of the catch of hatchery indicator stocks taken in fisheries wholly within the Strait of Georgia (p_{inside}). We emphasize that forecasts of distribution are actually forecasts of catch distribution assuming average historic patterns of effort distribution. However, coho fisheries have been highly restricted in the inside waters of sBC since 1997. Consequently there has been no estimate of p_{inside} since 1997 and the time series models that were developed for the 1998 forecast (Kadowaki and Holtby 1998) cannot be applied. However, we note that the salinity model, which was developed by Kadowaki et al (1996), outperformed the time-series models by a large margin in 1998. The salinity model predicts the proportion of catch taken in the strait if pre-1997 fishing regimes were in place and this proportion is now used as an index of inside distribution.

Surface salinity's measured at Sisters and Chrome island lighthouses in the year of return are positively correlated with p_{inside}. These islands are in the central Strait of Georgia. Salinity in February of the year of return is the best predictor of p_{inside} up to the time of the forecast.[4] Kadowaki (1997) averaged the daily February values from each lighthouse and then averaged the two means. Kadowaki et al. (1996) and Kadowaki and Holtby (1998) used the mean February salinity at Chrome Island only. Holtby et al. (2000) reverted to the average of Chrome and Sisters islands. Within and between lighthouse variances are typically not large over the month and the differences between the predictions are small and of no practical significance.

The regression model is:

$$Logit(\, p_{inside}\,) = b \bullet Sal + a \qquad \text{Eqn. 19}$$

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

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[4] The mean salinity from February to May is best of all (pers. comm., D. Blackbourn, 562 Bradley St., Nanaimo).

3.2 Retrospective Analyses

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

$$RMSE = \sqrt{\frac{\sum_{k=1}^{n}(n_{observed,k} - n_{predicted,k})^2}{n}} \qquad \text{Eqn. 20}$$

and the Mean Absolute Deviation (MAD):

$$MAD = \frac{\sum_{k=1}^{n}\left|(n_{observed,k} - n_{predicted,k})\right|}{n} \qquad \text{Eqn. 21}$$

Note that this calculation is performed in the variable space and not in the transformed space (Eqn. 8). Unlike time series models, regression models evolve with the addition of new data. Since the purpose was to assess the likely accuracy of current regression equations, we applied these updated equations to their time series to obtain the $n_{predicted}$ values needed in the above equations.

4. Forecasts of Survival - Strait of Georgia and wVI

4.1 Survivals in 2002

Estimates of survival in 2001 and 2002 are compared in the following table for the five hatchery indicators and three wild indicators.

Management Unit		Survival 2001	2002	Relative Change
GBW	Quinsam	0.016	0.013	-19%
	Big Qualicum	0.021	0.016	-22%
	Black (wild)	0.073	0.049	-33%
LowFr	Chilliwack	0.050	0.033	-35%
	Inch	0.062	0.021	-67%
	Salmon (wild)	0.064	0.063	-2%
	Mean, GBW-LowFr	0.048	0.032	-32%
SWVI, NWVI	Robertson	0.096	0.047	-51%
	Carnation (wild)	0.058	0.051	-13%

The survival of the wild SWVI indicator at Carnation Creek changed little from 2001. Robertson Hatchery coho survived like Carnation in 2002 but this was half of their survival in 2001. The 4.7% hatchery survival is average for the last five years and for the 27 year time series. The wild survival, 5.1%, is average since the 1990 brood year but below the 27 year average of 9.1%.

On the Strait of Georgia side of Vancouver Island (GBW), both hatchery indicator stocks continued to survive very poorly, declining from 2001 by about 20% into the 1% to 2% range. The 4.9% survival of Black Creek coho was more of a decline, but it was from a higher 2001 survival. Over the 16 year record, the Black survival was below average in 2002. In the shorter term, both hatchery and wild survivals in 2002 were similar to the average hatchery and average wild survivals since the mid-1990's. Although not yet an indicator due to a still short time series, coho from the Goldstream River Hatchery, near Victoria, only survived at 0.3% in 2002, down drastically from ~7% in 2001.

Once again, the Chilliwack and Inch hatchery indicator stocks in the LowFr Management Unit survived better than GBW hatcheries even though LowFr hatchery survivals decreased more from 2001. Survivals in 2002 were typical of the average survivals at these hatcheries since the mid 1990's. Like at Black, coho at Salmon River survived better than coho from hatchery indicators in the same MU. Salmon R. coho survival remained virtually unchanged from 2001 to 2002, unlike survivals elsewhere. The result was that, just as LowFr hatchery survivals were better than GBW hatchery survivals, Salmon survivals exceeded Black survivals in 2002.

Survival of coho declined in all sBC indicators in 2002: by 32% in the Georgia Basin and 37% in wVI. Compared to historic averages and estimates of marine survivals needed by wild populations of average productivity to sustain themselves (2% - 3%), Georgia Basin survivals were poor last year, particularly in GBW. They have been at these levels for about seven years now.

4.2 Forecast Performance in 2002

The performance of the 2002 forecasts (Simpson et al. 2002) is summarized in the following table and in Table 6 and Figure 4.

	Quinsam	Big Qualicum	Chilliwack	Inch	GB Hatcheries (mean)[1]	Black	Robertson	Carnation
Observed survival in 2002	0.013	0.016	0.033	0.021	0.021	0.049	0.047	0.051
Sibling forecast	0.023	0.070	0.041	0.023	0.039		0.031	0.161
% obs of forecast	56%	23%	80%	90%	53%		150%	32%
Quasi TS model	3YRA	LLY	RAT3	3YRA		3YRA	LLY	3YRA
Forecast	0.013	0.021	0.035	0.026	0.024	0.030	0.092	0.031
% obs of forecast	99%	77%	94%	79%	87%	162%	51%	164%
Euphausiid forecast								0.040
% obs of forecast								127%
CPUE forecast					0.034			
% obs of forecast					61%			

[1] Observed survivals in 2002 and the sibling and TS forecasts are row means of the corresponding values for the four hatcheries. The CPUE forecast is a regression using catches of juvenile coho.

The models with the best retrospective performances are shaded in the above table. These are the models with the least RMSE and MAD scores up to 2002. The survival forecasts proved to be too low for Black and Robertson coho, accurate for Quinsam and Chilliwack coho and slightly high for Big Qualicum and Inch coho. The CPUE forecast of general hatchery survival was too high. The mean of the sibling and time series forecasts for each hatchery were also too high, although the time series mean was fairly accurate. Observed survivals were all within the 50% confidence intervals of the forecasts except for Black and Carnation. The Carnation survival just exceeded the upper limit for the 50% interval (i.e. 75%). The Black forecast was the worst - the observed survival was within the 90% interval. Overall, the accuracy of the 2002 forecasts was better than average (cf. Simpson et al. 2001a, 2002).

4.3 Forecast of Survival in 2003

4.3.1 Euphausiid Model (Carnation Creek)

Standardized coefficients (Sokal and Rohlf 1995) for the present regression show that smolt and euphausiid abundances account for 74% and 26% of the explained variation respectively. (We found a similar relationship for Robertson Creek hatchery coho. However, this relationship broke down beginning in the 2000 return year). Table 7 summarizes the behavior of the parameter estimates and the performance of the regression over time. We began testing for significant regressions when the data series was five years long. Consequently analyses began with data up to and including the 1997 return year because we excluded data for 1994 (Section 3.1.4). The forecast shown for each year in Table 7 was calculated using only the data up to that year. Parameter estimates appeared to have stabilized as of the forecasts for the 2000 return year. Returns were under-estimated by one, eight and 13 fish in 2000, 2001 and 2002 respectively. Results are also presented as marine survival rates (Figure 5) because Carnation Creek is the indicator stream for SWVI and NWVI wild coho and smolt escapements differ among streams. Data for Kirby Creek, in Area 20, were available for the 2000 and 2001 return years. It appears that the survival rate forecasts were accurate for Kirby Creek and 2000 and 2001.

The regression used to forecast 2003 returns to Carnation Creek was estimated using the 1992-2002 return year time series, excluding 1994. The equation is:

$$\log_e A = 0.18 \bullet \log_e E + 0.81 \bullet \log_e S - 1.82 \qquad \text{Eqn. 22}$$

$R^2=0.99$, $p<0.001$, $n=10$

All parameter estimates are significantly different from zero ($p<0.05$). There were 4,613 smolts leaving Carnation Creek in 2002 and median *T. spinifera* abundance was 20 individuals • m^{-2}. The forecasted number of returning adults is 254 (95% CI: 223 – 291). The forecasted survival rate is 0.055 (95% CI: 0.048 - 0.063; Figure 10).

Retrospective analyses of sibling forecasts are done using the most recent regression equation. In order to compare the euphausiid forecast with the time series and sibling forecasts for Carnation, we applied the above equation to all years. We then converted the retrospective return forecasts to survivals. Except for the 1996 brood year, the current equation 'hindcasts' past survivals extremely well:

Brood Year	Retrospective Estimate	Observed	Observed - Estimated
1995	0.059	0.059	0.000
1996	0.051	0.010	-0.041
1997	0.049	0.048	-0.001
1998	0.055	0.055	0.000
1999	0.050	0.051	0.001

RMSE and MAD values were superior to either of the other methods, e.g. the euphausiid regression RMSE was .012 vs. .054 and .060 for the best time series model (3YRA) and the sibling regression.

4.3.2 Strait of Georgia CPUE Forecast

Hatchery CPUE, non-hatchery CPUE and total CPUE (Figure 6) were all significantly correlated with hatchery survival rates (Table 8 and Figure 7). Using the strongest relationship, we forecast that the survival of coho from hatcheries in the Georgia Basin will average 0.014 in 2003.

4.3.3 Time Series and Sibling Models

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

Management Unit	Indicator	Best Models			Alternate Models		
			$\hat{s}_{2003}$	(50% CI)		$\hat{s}_{2003}$	(50% CI)
GBW	Big Qualicum	LLY	0.016	(0.010 - 0.027)	Sibling	0.010	(0.006 - 0.017)
	Quinsam	3YRA	0.014	(0.011 - 0.018)	Sibling	0.006	(0.004 - 0.009)
	Black (wild)	3YRA	0.043	(0.030 - 0.061)	-		
LowFr	Chilliwack	RAT3	0.040	(0.029 - 0.055)	Sibling	0.034	(0.021 - 0.055)
	Inch	LLY	0.021	(0.009 - 0.047)	Sibling	0.031	(0.015 - 0.066)
	Salmon (wild)	LLY	0.063	(0.048 - 0.083)	-		
GBW, LowFr	Mean (hatcheries)[1]	CPUE	0.014	(0.011 - 0.017)	-		
SWVI, NWVI	Robertson	Sibling	0.047	(0.029 - 0.077)	LLY	0.047	(0.021 - 0.100)
	Carnation (wild)	Euphausiid	0.055	(0.053 - 0.058)	3YRA[2]	0.052	(0.028 - 0.095)
					Sibling	0.057	(0.037 - 0.089)

[1] This forecast regresses observed mean survivals of the above four hatcheries on CPUE data - the forecast does not equal the mean of individual forecasts (= 0.023).

[2] The best time series model (3YRA) has a better retrospective performance than the the sibling model.

All individual indicators in the Georgia Basin were best forecast with time series models (Figure 8 and Figure 9). Sibling and euphausiid regression models were selected in wVI for Robertson and Carnation respectively (Figure 10). The sibling regression for Robertson is shown in Figure 11. Wild survivals in GBW and LowFr, as indicated by Black Creek and Salmon River stocks, are forecast to remain the same as last year, i.e. 0.043 and 0.063, respectively.

The outlook for the Georgia Basin hatchery indicators is for poor survivals, similar to or less than 2002. The survival of Chilliwack coho is the only one that is predicted to increase to any extent (Table 11). Here the retrospective performance of the selected RAT3 model was barely better than the LLY model, i.e. forecasting no change at 0.033. The sibling forecast is poor for this stock but it also yields a no-change result (0.034). Overall, the CPUE forecast predicts a hatchery survival of 0.014, which is a 33% decline from the mean hatchery survival in 2002 of 0.021. The mean of the Georgia Basin hatchery survivals forecasted using time series models is 0.021 or 0.023, depending on which Chilliwack forecast is used, i.e. essentially the same as last year. The best sibling regressions in the Georgia Basin are for Big Qualicum and Quinsam (Table 9) and here the sibling forecasts support the time series conclusions that hatchery survivals will be particularly poor in the GBW MU.

The survival models also provide a consistent result for the two wVI indicators. We predict that survivals will be about the same as last year with wild stock (Carnation) survival of 0.05 to 0.06 and Robertson Hatchery survival of about 0.05. The Robertson survival is average for this stock and the Carnation forecast is average for the post-1990 period.

Overall, survival of wild coho in sBC is expected to be consistent between Units at 0.04 to 0.06. These survivals are similar to survivals in 2001 and 2002. Hatchery survivals are not expected to increase in 2003. Depending on the model, they are forecast to remain approximately the same (time series and sibling models) or hatchery survivals may decrease in the Georgia Basin (CPUE model).

5. Forecast of Abundance – Interior Fraser

5.1 Abundances in 2002

The abundance of Thompson watershed coho in 2002 was ~52,000, which exceeded the brood year (1999) abundance of ~18,600 (sum of S., N. and Lower Thompson in Table 3). Thompson escapements in 2002 (~48,400) were much greater than 1999 escapements (~17,000). These increases are attributed to reductions in the fishery and slight increases in marine survival over those observed for the brood year.

5.2 Forecast Performance in 2002

Forecasts of total abundance for 2002 provided in last year's forecast document (Simpson et al. 2002) were evaluated by comparing these forecasts with estimated coho abundance Table 12. The 3YRA model underestimated abundance to all sections of the Thompson system, and to the watershed as a whole. Forecasts were 36%, 50%, 55% and 48% of observed abundances for the Lower Thompson, South Thompson, North Thompson and total Thompson watershed, respectively. The 2001 forecast was also less than the observed abundance (Figure 12).

A retrospective prediction of 2002 abundances was also run using the 'return per spawner' (RS) based forecast method (Table 13). Although out-performing the abundance model predictions for 2002, the RS model also underestimated abundance to all sections of the Thompson system, and to the watershed as a whole. Forecasts were 78%, 60%, 55% and 55% of observed abundances for the Lower Thompson, South Thompson, North Thompson and total Thompson watersheds, respectively.

5.3 Forecast of Abundance in 2003

In addition to the 'abundance' based forecast performed in previous years (e.g. Simpson et. al 2002), 2003 forecasts for Thompson basin coho included the RS forecast, which was performed using the two averaging models (LLY and 3YRA) and the two ratio models (RAT1 and RAT3). As the ratio models produced unrealistic abundance predictions for the RS data set, only the averaging model results are presented. The best performing RS forecast was converted to an abundance forecast by multiplying by the brood year escapement in 2000.

Predictive performance of the 'abundance' models versus the RS models were compared through retrospective analysis (Table 14). While the RS model is designed to give weight to the effects of brood year escapement its predictions were consistently out-performed by the forecasts of the 'abundance' model. Forecast results and performance for both models are presented below, however as with past years, the abundance based forecasts are to be considered the official run size prediction in 2003.

In retrospective analysis, the averaging models (LLY and 3YRA) for the abundance data set once again outperformed the ratio models in forecasting total returns to the Thompson system (Table 15 and Table

16). With the exception of the LLY model in the South Thompson RS analysis, the 3YRA model continues to be the model of choice for the Thompson watershed for both the abundance and RS models. The time series of abundance estimates for coho in the Thompson River watershed is shown in Figure 12. The time series of reliable escapement data for non-Thompson systems in the interior Fraser is too short to evaluate model performance.

For both the abundance and RS models we forecast that the abundance of Thompson River coho in 2003 will be less than observed abundances in 2002 (Table 17; Table 18 and Figure 12). Based on the 3YRA abundance model, we predict ~35,700 coho will survive to adulthood and be available to return to the watershed. The forecast return to the Thompson River watershed is approximately 42% of the mean abundance of the time series. The 3YRA RS model makes a similar prediction of ~34,700 coho surviving to adulthood and available to return to the watershed. We are unable to forecast returns to the non-Thompson streams due to the extremely short time series of reliable escapement data (n=5).

6. Forecast of Abundance – Central Coast

6.1 Forecast Performance in 2002

Performance of the forecasts can be determined only for the average-stream indices in Statistical Area 7 (Table 19), Area 8 (Table 20), and Area 13 (Table 21). Total stock size was over-forecast for these three average stream indices. Forecasts were not provided for the Area 9/11 grouping or Statistical Area 12 in 2002. The reason why the forecast was high is unknown, but there were unusually low water conditions during the fall and early winter of 2002, and many of the escapement surveys may have ended before the entire escapement period had been enumerated. Further review of the reliability of escapement and exploitation rate information must take place. The two new coho indicators in the Central Coast (Martin River, Area 8, and Heydon River, Area 13) should eventually provide reliable escapement and exploitation rate information specific to this part of the coast.

6.2 Forecast of Abundance in 2003

The following table summarises the organisation of the forecast Tables and Figures. The Tables show the forecasts for total return (stock size) produced by the S-R and the best of the time series models, which in all cases was the three-year average (3YRA). Assuming that the exploitation rate in 2003 will be the same as this year, the forecast escapement is also shown for both models. The Tables also show the forecast escapements as percentages of the S_{max}, the spawner number that on average produces maximum recruitment.

Aggregate	preferred model	forecast summary Table	relevant Figure
Area 7 (Bella Bella)	3YRA	Table 22	Figure 13
Area 8 (Bella Coola)	3YRA	Table 23	Figure 14
Area 9/11 (Rivers/Seymour)	3YRA	Table 24	Figure 15
Area 12 (Johnstone Strait)	3YRA	Table 25	Figure 16
Area 13 (Johnstone Strait)	3YRA	Table 26	Figure 17

Table 27 summarises the results of the Ricker stock-recruitment model fits for the various coho aggregates. The time series for each aggregate are long and have at least an eight-fold range in S. However, the properties of these indices of aggregate abundance and their use in stock and recruitment analyses have not been explored. Although the forecast is believed to be conservative, considerable caution must be used in interpreting forecasts based on the stream indices.

The following table summarises the forecasts of abundance and escapement for the aggregates:

			Return (Abundance)		Escapement		
Area	Group	Recommended Model	Forecast P	Characterization	Forecast P	Characterization	% of S_{max} [1]
7	4	3YRA	28%	Below Average	58%	Average	38%
8	5	3YRA	15%	Below Average	40%	Average	43%
9 - 11	5	3YRA	38%	Average	91%	Well Above Average	129%
12	5	3YRA	13%	Well Below Average	48%	Average	27%
13	6	3YRA	2%	Well Below Average	19%	Below Average	6%

[1] The escapement that on average produces the maximum recruitment, as determined from the S-R analysis.

The "Forecast P" values are the proportions of observed abundances or escapements that were less than the forecast value. This calculation was made assuming a log-normal cumulative probability distribution with mean and standard deviation calculated over the observation period from 1950 (1953 for Areas 12 and 13) to 2002. Probability values between 35% and 65% were characterized as average; probabilities of less than 15% or greater than 85% were characterized as well below or well above average, respectively. "Groups" indicate groups made by Holtby et al. (1999b) for north coast and central coast coho, based on geography, distributions of CWT's in fisheries and on productivity. The group numbers are consistent with the 2002 forecast document for these aggregates (Holtby et al. 2002). This is a convenient way to summarise the forecasts because forecasts of abundance and escapement for average stream indices are useful only in the context of how far they deviate from the long-term means of their respective time series.

The forecasts for the JST aggregates are for poorer abundances than the aggregates to the north. The forecast of abundance in these JST aggregates is no better than well below-average. With continued restrictions to fisheries, i.e., no increases over 2002 levels of exploitation, escapement is forecast to be average in Area 12 and below average in Area 13. However, information is limited in this particular Statistical Area.

7. Forecast of Distribution – Strait of Georgia / wVI

The forecast of catch proportion inside is:

$$\log it(\hat{p}_{inside}) = 1.002 GSsal - 28.9 \qquad \text{Eqn. 23}$$

(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 (Sect. 3.1.6). The salinity at Sisters and Chrome islands averaged 28.63‰ in February, yielding a predicted value of 0.46. Figure 18 shows the fitted relationship and a probability plot of the confidence interval for p_{inside}. Confidence levels are tabulated in Table 28. An index of 0.46 is comparable to the long term mean and calls for more of an inside distribution than in 2002. It is also a stronger inside forecast than the mean of the previous 10 years (0.34; Simpson et al. 2001b). However, it cannot be characterized as a forecast for a strong inside year. For example, there is a 95% probability that 2003 will not be an 'inside year' as strong as the 0.70 forecast in 2001.

8. Conclusions

8.1 Survival and Abundance

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

Indicator	Recommended Model	Predicted Survival in 2003 (50% CI)	Change (2003 forecast minus 2002 observed)
Big Qualicum	LLY	0.016 (0.010 - 0.027)	0%
Quinsam	3YRA	0.014 (0.011 - 0.018)	8%
Chilliwack	RAT3	0.040 (0.029 - 0.055)	21%
Inch	LLY	0.021 (0.009 - 0.047)	0%
Str. of Georgia hatcheries	CPUE	0.014 (0.011 - 0.017)	-33%
Black (wild)	3YRA	0.043 (0.030 - 0.061)	-12%
Salmon (wild)	LLY	0.063 (0.048 - 0.083)	0%
Robertson	Sibling	0.047 (0.029 - 0.077)	0%
Carnation (wild)	Euphausiid	0.055 (0.053 - 0.058)	8%

Predictions by PSC Management Unit follow:

8.1.1 Georgia Basin West

Based on both time series and sibling forecasts, survival of coho on the east coast of Vancouver Island is expected to be poor, ranging from approximately 1.5% for hatcheries to 4.3% for higher productivity wild stocks like Black Creek. The expected hatchery survivals represent no change from 2002. Survival of Black Creek coho and perhaps other wild stocks declined in 2002 and the forecast is for similar survivals in 2003.

8.1.2 Georgia Basin East

We do not have sufficient information for a CWT-based estimate of survival from Myrtle Creek, our recently established indicator stock near Powell River. Spawner per smolt survivals of 2.8% and 2.6% in 2001 and 2002 suggest that survivals are at least as poor as in the GBW Management Unit.

8.1.3 Lower Fraser

The forecast survivals of Inch and Chilliwack hatchery coho of 2.1% and 4.0% and Salmon R. coho of 6.3% are not unusual survivals for these stocks since the mid-1990's. Inch and Salmon survivals are forecast to remain the same as in 2002. We would not characterize the wild survival forecast of 6.3% as 'poor' but it is below average (8.8% since 1987). Chilliwack and Inch hatchery survivals are further below their long term averages of 8.2% and 6.3%.

8.1.4 Georgia Basin (GBW, GBE, LowFr *in Toto*)

We present a CPUE survival forecast for hatchery coho in the Strait of Georgia of 1.4%, down from the 3.2% forecast for 2002. This is more precisely a forecast of the mean survival for the above four GBW and LowFr hatcheries. However, their survivals are strongly correlated with wild survivals and with abundances in IntFr. The observed mean survival to these indicators was 2.1% in 2002. There are only five years of data in the regression but so far the relationship with CPUE is strong. This forecast is consistent with three of the hatchery forecasts in magnitude but differs in predicting more of a decline in survivals in 2003.

Wild survival forecasts are consistent with hatchery forecasts overall: greater than hatchery forecasts and with the same trend expectations. These wild forecasts, recent wild survivals and the relative size of the CPUE forecast, all point to a continuing diminishment of harvestable surpluses compared to what would be available with historic survivals. The forecast models were particularly consistent this year. However, they have not been precise in the past: uncertainty in the forecasts coupled with below average survivals equate to continuing higher than average risk.

8.1.5 Southwest Vancouver Island and Northwest Vancouver Island

Forecasts of survival of Robertson Hatchery and Carnation Creek coho are for 4.7% and 5.5%, respectively. Both represent little change from survivals seen in the previous brood. We have more than usual confidence in these forecasts based on similar results from all models: sibling, time series and euphausiid. The expectation for higher wild than hatchery survivals is also consistent with the general pattern. Given that wild survivals in wVI are expected to be similar to Georgia Basin wild survivals, the comments in the previous section may apply. However, we think status is generally better in wVI, with moderate survivals the norm for several years. Georgia Basin stocks are viewed as being at higher risk due to low survivals for about three full cycles. We are more confident about these conclusions for SWVI. We have no indicator stocks in NWVI.

8.1.6 Interior Fraser (Thompson)

The forecast abundance of Thompson River watershed coho in 2003 is ~35,700, which is only 69% of the observed abundance in 2002. It does represent a forecasted increase over the 2000 brood abundance of 15,800 however. The escapement in 2002 was the second largest since 1989 and escapements in 2001 and

2002 were larger than brood year escapements. Greater proportions of fish that are surviving to maturity are returning to spawn because of the significant reductions in fishing pressure. Thus, assuming marine survivals and fishing pressures remain low, the outlook for Thompson and other interior Fraser coho is for slow improvement.

The RS model, while not outperforming the ‘abundance’ model in retrospective analysis, allows for the incorporation of brood year escapements into the forecasts. The inclusion of brood escapements may serve to strengthen the forecasting process in the future.

8.1.7 Central Coast

The stock-recruit and time series forecasts of abundance and escapement for the average-stream indices of the five Central Coast aggregates show some indication of geographic patterning. Abundance of coho in the northern part of the forecast region (Areas 7 and 8) is forecast to be below average in 2003. However, if fisheries do not expand much over levels in 2002, escapements are expected to be average. In Areas 9 to 11, the total abundance and escapement forecasts are characterized as average and well above average respectively. Abundances in Johnstone Strait streams (Areas 12 and 13) are expected to be well below average. Without further investigation of this situation and a demonstration that status is actually better than indicated by the indices used here, expansion of harvest rates on Area 12 and 13 coho should be extremely limited. Escapement and exploitation data in the Central Coast is poor and caution should be taken when interpreting these forecasts. Until further work is done on escapement assessment and exploitation rates for these stocks, careful consideration should be taken before expanding fisheries in these areas.

8.2 Distribution

Salinity data suggest that the proportion of 2000 brood coho residing in the Strait of Georgia in 2003 will be comparable to the long term mean. Although not a prediction of a strong ‘inside’ year, the proportion is expected to be more ‘inside’ than in 2002. This means that this stock group will be more susceptible to Strait of Georgia fisheries.

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TABLES

Table 1. Estimates of fishing mortality in 2001 on indicator stocks. Estimates do not include test fishing mortalities and only for Robertson (RCH) are mortalities from aboriginal and freshwater sport fisheries included. Mortality in 2002 was assumed to be the same.

Management Unit:	**SWVI**	**GBW**			**LowFr**			**IntFr**
Indicator:	**Robertson**	**Quinsam**	**Big Qualicum**	**Black**	**Inch**	**Chilliwack**	**Salmon[1]**	**Thompson**
Gillnet	0.1%	0.1%	1.0%	0.1%	0.3%	0.0%		0.0%
Seine	0.0%	0.2%	0.8%	0.3%	0.2%	0.0%		0.1%
Troll	0.4%	0.3%	0.2%	0.5%	0.4%	0.2%		0.4%
Marine Sport	10.8%	5.4%	5.6%	1.1%	6.2%	4.7%		0.7%
Southern US	0.4%	0.6%	1.0%	0.6%	2.6%	2.2%		5.6%
Alaska	1.0%	0.1%	0.1%	1.6%	0.0%	0.1%		0.3%
Mortality Estimate	12.7%	6.7%	8.7%	4.2%	9.7%	7.2%	0.0%	7.1%
Canadian Mortality	11.3%	6.0%	7.6%	2.0%	7.1%	4.9%	0.0%	1.2%

[1] Fishing mortality was assumed to be zero in the preliminary analysis for Salmon R. available for this report. A fishing mortality will be incorporated later. A likely estimate of < 5%mortality will make < 0.005 difference in survival estimates.

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

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

Table 3. Estimated fishery exploitation rates (ER), escapements (E), marine fishery catches, total abundances (R) and Returns per spawner (R/S) for interior Fraser coho salmon.

Return		South Thompson				North Thompson				Lower Thompson				Non-Thompson Fraser			
Year	ER	E	Catch	R	R/S	E	Catch	R	R/S	E	Catch	R	R/S	E	Catch	R	R/S
1975	0.68	5,864	12,490	18,354		22,286	47,468	69,754									
1976	0.68	3,920	8,349	12,268		20,675	44,037	64,713									
1977	0.68	8,490	18,082	26,572		42,804	91,171	133,975									
1978	0.68	7,996	17,032	25,028	4.27	39,095	83,269	122,364	5.49								
1979	0.68	10,198	21,720	31,918	8.14	47,819	101,851	149,670	7.24								
1980	0.68	7,025	14,964	21,989	2.59	10,542	22,454	32,996	0.77								
1981	0.68	4,120	8,775	12,895	1.61	20,615	43,909	64,524	1.65								
1982	0.68	5,849	12,459	18,308	1.80	42,295	90,087	132,382	2.77								
1983	0.68	6,196	13,196	19,392	2.76	35,086	74,731	109,816	10.42								
1984	0.68	15,394	32,789	48,183	11.69	69,552	148,141	217,692	10.56	5,155	12,050	17,205					
1985	0.68	16,998	36,205	53,204	9.10	45,160	96,188	141,349	3.34	1,913	4,060	5,973					
1986	0.66	16,521	31,665	48,186	7.78	104,267	199,846	304,113	8.67	2,211	4,300	6,511					
1987	0.54	21,087	24,478	45,564	2.96	54,884	63,710	118,594	1.71	4,208	4,945	9,153	1.78				
1988	0.71	24,426	60,376	84,802	4.99	70,612	174,539	245,150	5.43	4,013	9,830	13,843	7.24				
1989	0.65	17,208	31,288	48,496	2.94	30,677	55,779	86,455	0.83	3,423	6,340	9,763	4.42				
1990	0.74	8,609	24,069	32,677	1.55	25,697	71,844	97,542	1.78	4,421	12,600	17,021	4.04				
1991	0.68	4,160	8,737	12,896	0.53	14,585	30,633	45,217	0.64	3,794	8,825	12,619	3.14				
1992	0.81	11,886	52,239	64,125	3.73	22,042	96,875	118,917	3.88	4,905	21,000	25,905	7.57				
1993	0.88	1,873	13,172	15,045	1.75	9,669	67,999	77,667	3.02	8,416	61,500	69,916	15.82				
1994	0.43	4,485	3,430	7,915	1.90	10,031	7,671	17,702	1.21	5,252	3,965	9,217	2.43				
1995	0.56	3,622	4,639	8,261	0.70	22,477	28,794	51,272	2.33	1,984	2,525	4,509	0.92				
1996	0.83	1,760	8,906	10,667	5.70	12,319	62,325	74,645	7.72	1,209	5,900	7,109	0.84				
1997	0.40	2,034	1,384	3,418	0.76	6,722	4,573	11,295	1.13	4,217	2,820	7,037	1.34				
1998	0.07	4,946	375	5,321	1.47	9,125	685	9,810	0.44	2,628	200	2,828	1.43	8,147	610	8,757	
1999	0.09	3,074	305	3,379	1.92	8,916	885	9,801	0.80	5,007	495	5,502	4.55	5,389	535	5,924	
2000	0.034	3,785	134	3,919	1.93	7,032	250	7,282	1.08	4,459	157	4,616	1.09	4,723	144	4,867	
2001	0.071	13,044	997	14,041	2.84	26,838	2,051	28,889	3.17	10,450	799	11,249	4.28	13,515	1,033	14,548	1.79
2002	0.071	10,419	796	11,215	3.65	21,224	1,622	22,846	2.56	16,795	1,284	18,079	3.61	8,011	612	8,623	1.60

Table 4. Release and recovery summaries for the eight wild and hatchery indicator stocks used to generate survival forecasts.

Brood Year	CWT smolt release[1]	Jack (age x.0) Escapement	Adult (age x.1) Return	Adult (age x.1) Survival
Chilliwack R. Hatchery (LowFr)				
1981	28,502	287	4,090	0.143
1982	100,841	13	18,865	0.187
1983	27,851	143	3,664	0.132
1984	129,770	239	22,536	0.174
1985	59,935	743	10,847	0.181
1986	68,658	29	8,698	0.127
1987	39,250	244	4,166	0.106
1988	39,801	206	3,605	0.091
1989	39,500	149	2,245	0.057
1990	39,797	152	2,360	0.059
1991	39,673	82	2,536	0.064
1992	39,654	154	1,480	0.037
1993	39,808	191	1,584	0.040
1994	36,256	67	899	0.025
1995	74,456	131	1,001	0.013
1996	37,282	86	541	0.015
1997	82,059	85	1,921	0.023
1998	36,976	98	1,863	0.050
1999	42,795	87	1,411	0.033
2000	38,726	41		
Inch Cr. Hatchery (LowFr)				
1983	38,711	8	2,591	0.067
1984	38,774	150	3,449	0.089
1985	19,723	76	4,012	0.203
1986	19,504	12	2,116	0.109
1987	27,458	67	2,206	0.080
1988	38,019	36	2,700	0.071
1989	29,367	33	2,850	0.097
1990	31,629	91	2,611	0.083
1991	21,172	106	1,280	0.060
1992	20,303	4	1,116	0.055
1993	21,540	90	837	0.039
1994	21,174	5	223	0.011
1995	38,707	7	242	0.006
1996	41,918	7	888	0.021
1997	40,206	25	97	0.002
1998	40,201	0	2,489	0.062
1999	39,911	21	824	0.021
2000	39,998	22		

Table 4. (cont'd)

Brood Year	CWT smolt release[1]	Jack (age x.0) Escapement	Adult (age x.1) Return	Adult (age x.1) Survival
Salmon River (LowFr Wild Indicator)				
1984	7,891		1,216	0.154
1985	20,022		4,391	0.219
1986	24,634		3,324	0.135
1987	26,911		3,478	0.129
1988	20,390		1,583	0.078
1989	29,435		2,838	0.096
1990	28,141		2,374	0.084
1991	15,611		1,493	0.096
1992	35,256		2,452	0.070
1993	30,052		2,383	0.079
1994	24,719		850	0.034
1995	5,872		144	0.024
1996	38,368		1,005	0.026
1997	28,883	46	1,686	0.058
1998	25,163	237	1,657	0.066
1999	27,244	275	1,765	0.065
2000	21,603	26		
Quinsam R. Hatchery (GBW)				
1974	57,502	954	3,739	0.065
1975	97,560	1,923	7,134	0.097
1976	159,136	1,611	5,312	0.074
1977	168,286	1,419	11,932	0.101
1978	226,186	664	4,035	0.071
1979	280,127	1,382	4,255	0.048
1980	57,385	398	4,038	0.070
1981	102,021	639	5,533	0.054
1982	147,404	1,112	11,188	0.076
1983	57,764	861	9,266	0.092
1984	57,573	725	4,514	0.078
1985	42,176	910	3,351	0.079
1986	44,457	834	4,730	0.106
1987	39,362	776	3,068	0.078
1988	39,466	299	1,650	0.042
1989	39,400	243	2,317	0.059
1990	39,411	233	1,365	0.035
1991	42,470	314	965	0.023
1992	36,277	271	912	0.025
1993	38,947	129	536	0.014
1994	80,125	159	697	0.012
1995	82,351	486	586	0.009
1996	39,813	91	331	0.008
1997	39,322	201	528	0.013
1998	42,354	186	673	0.016
1999	42,999	201	553	0.013
2000	42,665	69		

Table 4. (cont'd)

Brood Year	CWT smolt release[1]	Jack (age x.0) Escapement	Adult (age x.1) Return	Adult (age x.1) Survival
Biq Qualicum Hatchery (GBW)				
1971	100,896	1,527	6,537	0.065
1972	100,933	1,176	36,951	0.366
1973	57,425	83	16,646	0.290
1974	75,512	1,085	12,416	0.164
1975	90,520	4,186	13,795	0.152
1976	38,748	974	7,485	0.193
1977	50,224	474	14,422	0.287
1978	45,328	439	5,757	0.127
1979	55,435	702	5,728	0.103
1980	51,984	265	5,802	0.112
1981	49,274	591	3,894	0.079
1982	42,453	177	2,130	0.050
1983	21,868	33	189	0.009
1984	87,365	71	542	0.006
1985	74,194	423	1,113	0.015
1986	27,462	96	355	0.013
1987	42,412	372	1,818	0.043
1988	44,813	246	2,759	0.062
1989	36,474	180	2,135	0.059
1990	37,362	353	2,492	0.067
1991	38,235	188	2,620	0.069
1992	37,957	48	1,115	0.029
1993	38,917	236	622	0.016
1994	37,616	79	536	0.014
1995	38,827	40	173	0.004
1996	40,331	135	449	0.011
1997	37,806	64	564	0.015
1998	40,836	133	851	0.021
1999	40,596	181	657	0.016
2000	41,543	57		
Black Creek (GBW Wild Indicator)				
1983	24,134	95	3,016	0.125
1984	31,648	46	3,617	0.114
1985	35,640	455	4,510	0.127
1986	74,997	305	8,529	0.114
1987	29,203	559	3,628	0.124
1988	118,382	824	9,028	0.076
1989	52,351	1,837	6,399	0.122
1990	49,873	1,710	3,156	0.063

Table 4. (cont'd)

Brood Year	CWT smolt release[1]	Jack (age x.0) Escapement	Adult (age x.1) Return	Adult (age x.1) Survival
Black Cr. (cont'd)				
1991	54,898	757	3,162	0.058
1992	76,003	1,214	3,459	0.046
1993	18,152	1,079	609	0.034
1994	13,736	280	597	0.043
1995	69,996	242	3,213	0.046
1996	24,582	523	407	0.017
1997	26,247	575	577	0.022
1998	151,129	1,950	10,990	0.073
1999	42,420	2,700	2,062	0.049
2000	88,421	72		
Robertson Cr. Hatchery (SWVI, NWVI)				
1972	44,536	1,625	2,963	0.067
1973	44,071	1,177	3,415	0.077
1974	55,672	1,040	4,011	0.072
1975	51,460	1,547	2,515	0.049
1976	43,047	464	3,773	0.088
1977	51,019	425	2,373	0.047
1978	51,916	307	1,168	0.022
1979	48,776	110	975	0.020
1980	144,742	1,035	8,193	0.057
1981	125,895	1,051	8,657	0.069
1982	94,740	44	1,932	0.020
1983	52,092	85	2,038	0.039
1984	46,061	41	1,335	0.029
1985	41,474	86	765	0.018
1986	50,967	396	2,514	0.049
1987	61,191	608	5,525	0.090
1988	43,524	139	2,567	0.059
1989	41,773	57	1,926	0.046
1990	40,221	140	963	0.024
1991	38,419	0	18	0.000
1992	36,873	2	464	0.013
1993	42,248	23	755	0.018
1994	43,005	228	1,310	0.030
1995	39,566	54	1,389	0.035
1996	39,578	57	834	0.021
1997	40,499	66	4,161	0.103
1998	40,207	83	3,843	0.096
1999	40,068	70	1,864	0.047
2000	40,317	162		

Table 4. (cont'd)

Brood Year	CWT smolt release[1]	Jack (age x.0) Escapement	Adult (age x.1) Return	Adult (age x.1) Survival
Carnation Creek (SWVI, NWVI Wild Indicator)				
1972	2,658	75	327	0.123
1973	2,121	54	260	0.123
1974	3,062	35	268	0.088
1975	2,560	53	172	0.067
1976	4,646	233	708	0.152
1977	3,530	114	324	0.092
1978	4,567	101	235	0.052
1979	4,164	61	525	0.126
1980	3,470	61	321	0.092
1981	3,745	83	200	0.053
1982	3,113	25	188	0.060
1983	1,978	59	323	0.163
1984	2,833	27	143	0.050
1985	2,648	58	204	0.077
1986	2,712	98	514	0.190
1987	3,862	160	599	0.155
1988	3,222	128	609	0.189
1989	3,103	51	385	0.124
1990	5,253	43	388	0.074
1991	3,989	6	24	0.006
1992	4,759	104	432	0.091
1993	3,480	90	165	0.047
1994	892	85	76	0.085
1995	4,942	123	293	0.059
1996	4,865	69	49	0.010
1997	2,842	79	136	0.048
1998	4,828	86	281	0.058
1999	2,005	115	102	0.051
2000	4,613	81		

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

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

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

Brood Year	Catch Year	No. of Sets	Catch Ad Clip	Catch Not Clipped	Catch Total
1995	1997	69	158	307	465
1996	1998	95	474	789	1,263
1997	1999	98	660	989	1,649
1998	2000	85	2,144	406	2,550
1999	2001	107	2,572	577	3,149
2000	2002	91	811	1,071	1,882

Table 6. Performance of survival forecasts for 2002, showing the model, the observed survival and the forecast with confidence limits.

	Strait of Georgia Indicators						wVI Indicators	
	Quinsam	Big Qualicum River	Chilliwack	Inch	GB Hatcheries (Mean)	Black (wild)	Robertson	Carnation (wild)
Survival 2002 (observed)	**0.013**	**0.016**	**0.033**	**0.021**	**0.021**	**0.049**	**0.047**	**0.051**
Model	3YRA	LLY	RAT3	3YRA	CPUE	3YRA	Sibling	Euphausiid
CI:75%[1]	0.018	0.032	0.049	0.050	0.036	0.042	0.049	0.048
Forecast	**0.013**	**0.021**	**0.035**	**0.026**	**0.034**	**0.030**	**0.031**	**0.040**
CI:25%	0.010	0.014	0.025	0.013	0.031	0.021	0.019	0.034
CI:10%	0.008	0.009	0.018	0.007	0.028	0.015	0.013	0.028
CI:5%	0.007	0.007	0.015	0.004	0.026	0.012	0.010	0.025
CI:1%	0.005	0.004	0.010	0.002	0.018	0.008	0.006	0.018

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

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

Forecast				Regression coefficients					Returning Adults	
Year	n	Ln smolts	Ln *T.spinifera*	Intercept	Smolts	*T. spinifera*	R^2	p	Predicted	Observed
1998	5	8.50	3.33	-8.64	1.58	0.49	0.99	0.005	615	292
1999	6	8.49	2.52	-2.99	1.01	0.11	0.98	0.001	351	49
2000	7	7.96	1.79	-1.87	0.81	0.18	0.98	0.001	134	135
2001	8	8.48	2.94	-1.85	0.81	0.18	0.98	0.001	257	265
2002	9	7.60	1.60	-1.93	0.82	0.19	0.99	0.001	89	102

Table 8. Catch per unit effort of age x.0 coho in the Strait of Georgia during July trawl surveys and the mean marine survival of coho from Chilliwack, Inch, Big Qualicum and Quinsam hatcheries. Ad-clipped CPUE provided the best linear regression fit to survival (shaded cells).

Brood	Catch	CPUE			Mean Hatchery
Year	Year	Ad-Clipped	No Mark	Total	Survival (S)
1995	1997	7.58	4.55	12.13	0.010
1996	1998	14.19	12.62	26.81	0.013
1997	1999	20.61	13.22	33.83	0.013
1998	2000	68.45	40.4	108.85	0.036
1999	2001	59.98	41.67	101.65	0.020
2000	2002	17.71	23.38	41.09	
Regression:	Logit (S) = b * ln (CPUE) + a				
	a	-5.715	-	-5.982	
	b	0.506	-	0.508	
	adj R^2	0.788	-	0.767	
	Probability	0.028	-	0.033	
	Forecast	**0.014**	-	0.017	
	(50% CI)	**(0.011 - 0.017)**		(0.013 - 0.020)	

Table 9. Forecasts, using sibling regressions, of adult returns and survivals in 2003 for the four Strait of Georgia hatchery indicators and two wVI indicators.

	Big Qualicum	**Chilliwack**	**Quinsam**	**Inch**	**Robertson**	**Carnation**
a (intercept)	1.786	5.221	0.805	6.473	4.974	2.709
b (slope)	1.051	0.528	1.121	0.212	0.505	0.652
N	25	19	26	17	28	28
r^2 adjusted	0.74	0.30	0.77	0.02	0.62	0.32
Tagged Smolt Release (2002)[1]	41,543	38,726	42,665	39,998	40,317	4,613
Jack Escapement (2002)	57	41	69	22	162	81
Predicted Adult Return (2003)	415	1,315	259	1,247	1,888	264
Predicted Survival (2003)	**0.010**	**0.034**	**0.006**	**0.031**	**0.047**	**0.057**
Confidence Intervals:						
1%	0.002	0.006	0.001	0.002	0.008	0.011
5%	0.003	0.010	0.002	0.005	0.014	0.019
10%	0.004	0.013	0.003	0.007	0.018	0.024
25%	0.006	0.021	0.004	0.015	0.029	0.037
75%	0.017	0.055	0.009	0.066	0.077	0.089

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

Table 10. Time series forecasts of survival of adult coho returning to southern BC indicators in 2003.

	Strait of Georgia Indicators						wVI Indicators	
	Quinsam	Big Qualicum	Chilliwack	Inch	Black (wild)	Salmon (wild)	Robertson	Carnation (wild)
Model	3YRA	LLY	RAT3	LLY	3YRA	LLY	LLY	3YRA
CI:75%[1]	0.018	0.027	0.055	0.047	0.061	0.083	0.100	0.095
2003 forecast	**0.014**	**0.016**	**0.040**	**0.021**	**0.043**	**0.063**	**0.047**	**0.052**
CI:25%	0.011	0.010	0.029	0.009	0.030	0.048	0.021	0.028
CI:10%	0.008	0.006	0.021	0.004	0.022	0.037	0.010	0.016
CI:5%	0.007	0.004	0.018	0.002	0.017	0.032	0.006	0.011
CI:1%	0.005	0.002	0.012	0.001	0.011	0.023	0.002	0.005

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

Table 11. Best forecast models for 2003 and the relation of 2003 forecasts to survivals in 2002.

Indicator	Recommended Model	Predicted Survival in 2003 (50% CI)	Change (2003 forecast minus 2002 observed)
Big Qualicum	LLY	0.016 (0.010 - 0.027)	0%
Quinsam	3YRA	0.014 (0.011 - 0.018)	8%
Chilliwack	RAT3	0.040 (0.029 - 0.055)	21%
Inch	LLY	0.021 (0.009 - 0.047)	0%
Str. of Georgia hatcheries	CPUE[1]	0.014 (0.011 - 0.017)	-33%
Black (wild)	3YRA	0.043 (0.030 - 0.061)	-12%
Salmon (wild)	LLY	0.063 (0.048 - 0.083)	0%
Robertson	Sibling	0.047 (0.029 - 0.077)	0%
Carnation (wild)	Euphausiid	0.055 (0.053 - 0.058)	8%

[1] This forecast regresses observed mean survivals of the above four hatcheries on CPUE data - the forecast does not equal the mean of individual forecasts using other models (=0.23).

Table 12. Performance of 2002 forecasts of total abundance for the Thompson River watershed. All forecasts were based on the 3YRA abundance based model.

	Lower Thompson		South Thompson		North Thompson		Total Thompson	
CI	Forecast	Observed	Forecast	Observed	Forecast	Observed	Forecast	Observed
99%	5.6E+04		3.1E+04		8.7E+04		1.5E+05	
95%	2.8E+04		1.8E+04		4.7E+04		8.4E+04	
90%	2.0E+04		1.4E+04		3.5E+04		6.3E+04	
75%	1.2E+04		8.9E+03		2.1E+04		4.0E+04	
50%	**6.6E+03**	**1.8E+04**	**5.6E+03**	**1.1E+04**	**1.2E+04**	**2.3E+04**	**2.5E+04**	**5.2E+04**
25%	3.8E+03		3.5E+03		7.3E+03		1.5E+04	
10%	2.2E+03		2.3E+03		4.5E+03		9.8E+03	
5%	1.6E+03		1.7E+03		3.3E+03		7.4E+03	
1%	7.8E+02		1.0E+03		1.8E+03		4.1E+03	

Table 13. Performance of 2002 forecasts of total abundance for the Thompson River watershed. All forecasts are based on the 3YRA returns per spawner model.

	Lower Thompson		South Thompson		North Thompson		Total Thompson	
CI	Forecast	Observed	Forecast	Observed	Forecast	Observed	Forecast	Observed
99%	2.4E+05		6.6E+04		2.0E+05		3.0E+05	
95%	9.2E+04		3.2E+04		8.5E+04		1.4E+05	
90%	5.9E+04		2.2E+04		5.4E+04		9.5E+04	
75%	2.9E+04		1.3E+04		2.7E+04		5.3E+04	
50%	**1.41E+04**	**1.81E+04**	**6.72E+03**	**1.12E+04**	**1.25E+04**	**2.28E+04**	**2.87E+04**	**5.21E+04**
25%	6.8E+03		3.6E+03		5.8E+03		1.6E+04	
10%	3.4E+03		2.0E+03		2.9E+03		8.7E+03	
5%	2.2E+03		1.4E+03		1.8E+03		6.0E+03	
1%	8.3E+02		6.8E+02		7.6E+02		2.7E+03	

Table 14. A comparison of the predictive power of abundance versus return per spawner based models using retrospective analysis.

North Thompson

MA-1 model (Like Last Year)						MA-3 (moving 3 yr average)					
ABUNDANCE BASED MODEL			RETURN PER SPAWNER			ABUNDANCE BASED MODEL			RETURN PER SPAWNER		
1979-2002	*RMSE*	8.16E+04	1979-2002	*RMSE*	1.75.E+05	1982-2002	*RMSE*	6.52E+04	1982-2002	*RMSE*	1.27E+05
	MAD	6.14E+04		MAD	1.074E+05		MAD	4.93E+04		MAD	7.95E+04
	n	24		*n*	24		*n*	21		*n*	21
	stdev:	0.8790		stdev:	1.3589		stdev:	0.7845		stdev:	1.1505
1990-2002	*RMSE*	3.90E+04	1990-2002	*RMSE*	4.69E+04	1990-2002	*RMSE*	3.60E+04	1990-2002	*RMSE*	4.41E+04
	MAD	3.01E+04		MAD	3.613E+04		MAD	2.78E+04		MAD	3.16E+04
	n	13		*n*	13		*n*	13		*n*	13
	stdev:	0.9435		stdev:	1.0723		stdev:	0.8372		stdev:	1.0353

South Thompson

MA-1 model (Like Last Year)						MA-3 (moving 3 yr average)					
ABUNDANCE BASED MODEL			RETURN PER SPAWNER			ABUNDANCE BASED MODEL			RETURN PER SPAWNER		
1979-2002	*RMSE*	2.03E+04	1979-2002	*RMSE*	2.71E+04	1981-2002	*RMSE*	1.86E+04	1981-2002	*RMSE*	3.16.E+04
	MAD	1.33E+04		MAD	1.94E+04		MAD	1.38E+04		MAD	2.06E+04
	n	27		*n*	24		*n*	22		*n*	22
	stdev:	0.6927		stdev:	1.3326		stdev:	0.7229		stdev:	0.9172
1990-2002	*RMSE*	2.13E+04	1990-2002	*RMSE*	2.08E+04	1990-2002	*RMSE*	1.79E+04	1990-2002	*RMSE*	2.34E+04
	MAD	1.31E+04		MAD	1.41E+04		MAD	1.28E+04		MAD	1.44E+04
	n	13		*n*	13		*n*	13		*n*	13
	stdev:	0.8850		stdev:	1.1605		stdev:	0.7960		stdev:	0.9026

Lower Thompson

MA-1 model (Like Last Year)						MA-3 (moving 3 yr average)					
ABUNDANCE BASED MODEL			RETURN PER SPAWNER			ABUNDANCE BASED MODEL			RETURN PER SPAWNER		
1988-2002	*RMSE*	2.01E+04	1988-2002	*RMSE*	1.77.E+04	1990-2002	*RMSE*	1.75E+04	1990-2002	*RMSE*	1.82E+04
	MAD	1.11E+04		MAD	1.106E+04		MAD	1.09E+04		MAD	1.20E+04
	n	15		*n*	15		*n*	13		*n*	13
	stdev:	0.8136		stdev:	1.0424		stdev:	0.9064		stdev:	1.1236
1990-2002	*RMSE*	2.15E+04	1990-2002	*RMSE*	1.87E+04	1990-2002	*RMSE*	1.75E+04	1990-2002	*RMSE*	1.82E+04
	MAD	1.21E+04		MAD	1.148E+04		MAD	1.09E+04		MAD	1.20E+04
	n	13		*n*	13		*n*	13		*n*	13
	stdev:	0.8649		stdev:	1.0654		stdev:	0.9064		stdev:	1.1236

Total Thompson

MA-1 model (Like Last Year)						MA-3 (moving 3 yr average)					
ABUNDANCE BASED MODEL			RETURN PER SPAWNER			ABUNDANCE BASED MODEL			RETURN PER SPAWNER		
1988-2002	*RMSE*	2.01E+04	1988-2002	*RMSE*	1.58E+05	1990-2002	*RMSE*	1.75E+04	1990-2002	*RMSE*	7.11E+04
	MAD	1.11E+04		MAD	8.87E+04		MAD	1.09E+04		MAD	5.24E+04
	n	15		*n*	15		*n*	13		*n*	13
	stdev:	0.8136		stdev:	0.9738		stdev:	0.9064		stdev:	0.5750
1990-2002	*RMSE*	2.15E+04	1990-2002	*RMSE*	6.70E+04	1990-2002	*RMSE*	1.75E+04	1990-2002	*RMSE*	7.11E+04
	MAD	1.21E+04		MAD	4.57E+04		MAD	1.09E+04		MAD	5.24E+04
	n	13		*n*	13		*n*	13		*n*	13
	stdev:	0.8649		stdev:	0.9067		stdev:	0.9064		stdev:	0.5750

Table 15. Retrospective analysis of performance of four time series models where abundance data were used to predict coho abundance in the interior Fraser. The recommended models are shaded.

		LLY	3YRA	RAT1	RAT3
South Thompson	*RMSE*	20,315	18,021	89,303	25,427
	MAD	13,324	13,378	36,955	18,226
	n	27	25	26	24
North Thompson	*RMSE*	81,606	65,330	193,149	112,269
	MAD	61,415	50,200	132,809	78,372
	n	27	24	26	24
Lower Thompson	*RMSE*	20,081	16,396	52,134	30,187
	MAD	11,088	9,940	20,831	14,146
	n	18	16	17	15
Total Thompson	*RMSE*	89,540	70,937	224,111	110,249
	MAD	62,415	57,751	145,835	78,837
	n	18	16	17	15
Fraser/non-Thompson	*RMSE*	5,873	NA	24,700	NA
	MAD	4,874	NA	17,593	NA
	n	4	2	3	-
Total Interior Fraser	*RMSE*	24,279	NA	118,114	NA
	MAD	15,348	NA	83,497	NA
	n	4	2	3	-

Table 16. Retrospective analysis of performance of four time series models where return per spawner data were used to predict coho abundance in the interior Fraser. The recommended models are shaded.

		LLY	3YRA
South Thompson	*RMSE*	3.02	3.19
	MAD	2.13	2.16
	n	25	22
North Thompson	*RMSE*	3.90	3.40
	MAD	2.95	2.51
	n	25	22
Lower Thompson	*RMSE*	5.01	4.31
	MAD	3.27	3.14
	n	15	13
Total Thompson	*RMSE*	1.95	1.72
	MAD	1.43	1.51
	n	15	13

Table 17. Forecasts of total abundance for Thompson River watershed coho in 2003 and associated confidence intervals. All forecasts are based on the 3YRA 'abundance' based 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=16		n=25		n=25		n=16	
99%	83,000	829%	47,000	263%	120,000	195%	230,000	272%
95%	41,000	409%	28,000	156%	63,000	103%	130,000	154%
90%	29,000	289%	21,000	117%	47,000	77%	94,000	111%
75%	17,000	170%	14,000	78%	28,000	46%	59,000	70%
50%	**9,600**	**96%**	**8,500**	**47%**	**17,000**	**28%**	**36,000**	**43%**
25%	5,400	54%	5,300	30%	9,800	16%	22,000	26%
10%	3,200	32%	3,400	19%	6,000	10%	14,000	17%
5%	2,300	23%	2,600	15%	4,400	7%	10,000	12%
1%	1,100	11%	1,500	8%	2,400	4%	5,400	6%

Table 18. Forecasts of total abundance for Thompson River watershed coho in 2003 and associated confidence intervals. All forecasts with the exception of the S. Thompson (LLY) are based on the 3YRA 'return per spawner' 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=13		n=22		n=22		n=13	
99%	1.7E+05	1670%	1.7E+05	936%	2.2E+05	366%	3.4E+05	400%
95%	6.8E+04	676%	7.7E+04	429%	9.5E+04	154%	1.6E+05	189%
90%	4.4E+04	440%	5.2E+04	289%	6.1E+04	100%	1.1E+05	132%
75%	2.3E+04	227%	2.7E+04	154%	3.1E+04	50%	6.3E+04	75%
50%	**1.1E+04**	**112%**	**1.4E+04**	**77%**	**1.4E+04**	**23%**	**3.5E+04**	**41%**
25%	5.6E+03	56%	7.0E+03	39%	6.8E+03	11%	1.9E+04	23%
10%	2.9E+03	29%	3.7E+03	21%	3.4E+03	5%	1.1E+04	13%
5%	1.9E+03	19%	2.5E+03	14%	2.2E+03	4%	7.5E+03	9%
1%	7.6E+02	8%	1.1E+03	6%	9.2E+02	1%	3.6E+03	4%

Table 19. Performance of the 2002 forecast total return for the Area 7 aggregate. Stock-recruitment and time series models were used to forecast in 2002. The preferred model is underlined.

	total return		
	observed	2002 forecast	
probability of a lower value		S-R	<u>3YRA</u>
99%		2.6E+03	2.0E+03
95%		1.8E+03	1.4E+03
90%		1.5E+03	1.1E+03
75%		1.1E+03	8.2E+02
50%	**7.8E+02**	8.8E+02	5.8E+02
25%		7.0E+02	4.0E+02
10%		5.7E+02	2.9E+02
5%		5.0E+02	2.4E+02
1%		4.1E+02	1.6E+02

Table 20. Performance of the 2002 forecast total return for the Area 8 aggregate. Stock-recruitment and time series models were used to forecast in 2002. The preferred model is underlined.

	total return		
	observed	2002 forecast	
probability of a lower value		S-R	<u>3YRA</u>
99%		1.3E+04	9.2E+03
95%		9.2E+03	6.2E+03
90%		7.7E+03	5.1E+03
75%		6.0E+03	3.6E+03
50%	**1.2E+03**	**4.6E+03**	**2.5E+03**
25%		3.6E+03	1.7E+03
10%		2.9E+03	1.2E+03
5%		2.5E+03	1.0E+03
1%		2.0E+03	6.8E+02

Table 21. Performance of the 2002 forecast total return for the Area 13 aggregate. Stock-recruitment and time series models were used to forecast in 2002. The preferred model is underlined.

probability of a lower value	total return		
	observed	2002 forecast	
		S-R	<u>3YRA</u>
99%		4.1E+03	1.5E+03
95%		2.6E+03	1.1E+03
90%		2.1E+03	8.8E+02
75%		1.5E+03	6.5E+02
50%	**1.1E+02**	**1.1E+03**	**4.6E+02**
25%		8.0E+02	3.3E+02
10%		6.0E+02	2.4E+02
5%		5.0E+02	2.0E+02
1%		3.5E+02	1.4E+02

Table 22. For the Area 7 aggregate, 2003 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. *Z*-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.20 was assumed. The 3YRA is the preferred model.

P§	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	3YRA	z-score	S-R	z-score	3YRA	z-score	S-R	3YRA
99%	1.6E+03	1.42	1.5E+03	1.26	1.2E+03	3.50	1.2E+03	3.26	111%	106%
95%	1.2E+03	0.74	1.1E+03	0.44	9.9E+02	2.41	8.7E+02	1.93	88%	77%
90%	1.1E+03	0.46	9.2E+02	0.11	8.7E+02	1.96	7.4E+02	1.39	78%	66%
75%	9.1E+02	0.07	7.1E+02	-0.33	7.2E+02	1.34	5.7E+02	0.68	65%	50%
50%	**7.4E+02**	**-0.26**	**5.3E+02**	**-0.69**	**6.0E+02**	**0.80**	**4.2E+02**	**0.10**	**53%**	**38%**
25%	6.2E+02	-0.51	4.0E+02	-0.97	5.0E+02	0.39	3.2E+02	-0.34	44%	28%
10%	5.3E+02	-0.69	3.0E+02	-1.16	4.2E+02	0.10	2.4E+02	-0.65	38%	22%
5%	4.9E+02	-0.78	2.6E+02	-1.25	3.9E+02	-0.05	2.1E+02	-0.80	35%	18%
1%	4.2E+02	-0.93	1.9E+02	-1.39	3.3E+02	-0.28	1.5E+02	-1.03	30%	13%

§probability of a lower value

Table 23. For the Area 8 aggregate, 2003 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. Z-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.20 was assumed. The 3YRA is the preferred model.

$P^{§}$	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	3YRA	z-score	S-R	z-score	3YRA	z-score	S-R	3YRA
99%	8.0E+03	3.53	5.0E+03	1.51	6.4E+03	7.91	4.0E+03	4.26	360%	226%
95%	5.3E+03	1.68	3.3E+03	0.31	4.2E+03	4.57	2.6E+03	2.07	238%	146%
90%	4.3E+03	1.00	2.6E+03	-0.13	3.4E+03	3.33	2.1E+03	1.27	192%	117%
75%	3.0E+03	0.17	1.8E+03	-0.67	2.4E+03	1.82	1.4E+03	0.29	137%	81%
50%	**2.1E+03**	**-0.45**	**1.2E+03**	**-1.08**	**1.7E+03**	**0.69**	**9.6E+02**	**-0.44**	**96%**	**54%**
25%	1.5E+03	-0.87	8.0E+02	-1.35	1.2E+03	-0.06	6.4E+02	-0.93	68%	36%
10%	1.1E+03	-1.12	5.6E+02	-1.51	9.1E+02	-0.52	4.5E+02	-1.23	51%	25%
5%	9.6E+02	-1.24	4.4E+02	-1.59	7.7E+02	-0.73	3.6E+02	-1.37	43%	20%
1%	7.2E+02	-1.40	2.9E+02	-1.70	5.8E+02	-1.03	2.3E+02	-1.56	33%	13%

§probability of a lower value

Table 24. For the Area 9/11 aggregate, 2003 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. Z-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.20 was assumed. The 3YRA is the preferred model.

$P^{§}$	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	3YRA	z-score	S-R	z-score	3YRA	z-score	S-R	3YRA
99%	4.0E+03	3.26	6.2E+03	6.17	3.2E+03	7.38	5.0E+03	12.51	374%	578%
95%	2.9E+03	1.78	3.9E+03	3.14	2.3E+03	4.79	3.1E+03	7.17	270%	365%
90%	2.5E+03	1.21	3.1E+03	2.04	2.0E+03	3.77	2.5E+03	5.24	230%	288%
75%	1.9E+03	0.46	2.1E+03	0.72	1.5E+03	2.46	1.7E+03	2.92	178%	196%
50%	**1.5E+03**	**-0.14**	**1.4E+03**	**-0.24**	**1.2E+03**	**1.41**	**1.1E+03**	**1.23**	**136%**	**129%**
25%	1.1E+03	-0.56	9.0E+02	-0.87	9.1E+02	0.66	7.2E+02	0.12	106%	84%
10%	9.2E+02	-0.85	6.1E+02	-1.25	7.4E+02	0.16	4.9E+02	-0.56	86%	57%
5%	8.2E+02	-0.98	4.9E+02	-1.43	6.6E+02	-0.08	3.9E+02	-0.86	76%	45%
1%	6.7E+02	-1.18	3.1E+02	-1.66	5.4E+02	-0.43	2.5E+02	-1.28	62%	29%

§probability of a lower value

Table 25. For the Area 12 aggregate, 2003 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. *Z*-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.05 was assumed. The 3YRA is the preferred model.

$P^{§}$	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	3YRA	z-score	S-R	z-score	3YRA	z-score	S-R	3YRA
99%	1.4E+04	2.36	5.4E+03	0.18	1.3E+04	8.44	5.2E+03	2.62	304%	120%
95%	8.9E+03	1.07	3.5E+03	-0.33	8.4E+03	4.99	3.3E+03	1.25	195%	76%
90%	7.0E+03	0.60	2.7E+03	-0.52	6.7E+03	3.73	2.6E+03	0.76	155%	60%
75%	4.9E+03	0.04	1.9E+03	-0.74	4.6E+03	2.23	1.8E+03	0.16	107%	41%
50%	**3.3E+03**	**-0.38**	**1.2E+03**	**-0.91**	**3.1E+03**	**1.13**	**1.2E+03**	**-0.28**	**72%**	**27%**
25%	2.3E+03	-0.64	8.2E+02	-1.02	2.1E+03	0.42	7.8E+02	-0.58	50%	18%
10%	1.6E+03	-0.81	5.6E+02	-1.08	1.5E+03	-0.02	5.3E+02	-0.76	36%	12%
5%	1.3E+03	-0.88	4.4E+02	-1.11	1.3E+03	-0.21	4.2E+02	-0.84	30%	10%
1%	9.7E+02	-0.98	2.8E+02	-1.16	9.2E+02	-0.47	2.7E+02	-0.95	21%	6%

§probability of a lower value

Table 26. For the Area 13 aggregate, 2003 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. *Z*-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.05 was assumed. The 3YRA is the preferred model.

$P^{§}$	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	3YRA	z-score	S-R	z-score	3YRA	z-score	S-R	3YRA
99%	2.2E+03	0.44	8.0E+02	-0.70	2.1E+03	4.08	7.6E+02	0.72	72%	26%
95%	1.4E+03	-0.21	5.1E+02	-0.94	1.3E+03	2.16	4.8E+02	0.01	46%	17%
90%	1.1E+03	-0.45	4.0E+02	-1.03	1.1E+03	1.46	3.8E+02	-0.25	36%	13%
75%	7.6E+02	-0.73	2.7E+02	-1.13	7.2E+02	0.62	2.6E+02	-0.56	25%	9%
50%	**5.0E+02**	**-0.94**	**1.8E+02**	**-1.21**	**4.8E+02**	**0.01**	**1.7E+02**	**-0.78**	**17%**	**6%**
25%	3.4E+02	-1.08	1.2E+02	-1.26	3.2E+02	-0.39	1.1E+02	-0.93	11%	4%
10%	2.4E+02	-1.16	8.0E+01	-1.29	2.3E+02	-0.64	7.6E+01	-1.02	8%	3%
5%	1.9E+02	-1.20	6.3E+01	-1.31	1.8E+02	-0.74	6.0E+01	-1.06	6%	2%
1%	1.3E+02	-1.25	4.0E+01	-1.33	1.3E+02	-0.89	3.8E+01	-1.12	4%	1%

§probability of a lower value

Table 27. Summary of the Ricker stock-recruitment analyses on reconstructed time series for the Statistical Area aggregates.

	Ricker stock-recruitment analysis						
aggregate	*N*	adj. r^2	*a'*	*b'*	S_{MSY}	S_{MAX}[§]	u_{MSY}
Area 7	49	0.32	1.33	1240	505	931	0.54
Area 8	49	0.36	1.87	2771	1023	1482	0.69
Area 9/11	49	0.48	1.90	1358	499	715	0.70
Area 12	46	0.27	1.72	6200	2353	3601	0.65
Area 13	46	0.05	1.53	3698	1452	2411	0.60

[§] The spawner number producing on average the maximum recruitment.

Table 28. Forecast of p_{inside} in 2003 for Strait of Georgia hatchery indicators, where p_{inside} is an index of the proportion of coho residing in the Strait in their second year of ocean life.

Parameter	$\boldsymbol{p}$ **inside**
a	-28.9
b	1.002
N	23
Confidence Intervals:	
1% lower	0.162
5% lower	0.236
10% lower	0.280
25% lower	0.361
Forecast	**0.458**
75% lower	0.559
90% lower	0.647
95% lower	0.699
99% lower	0.788

FIGURES

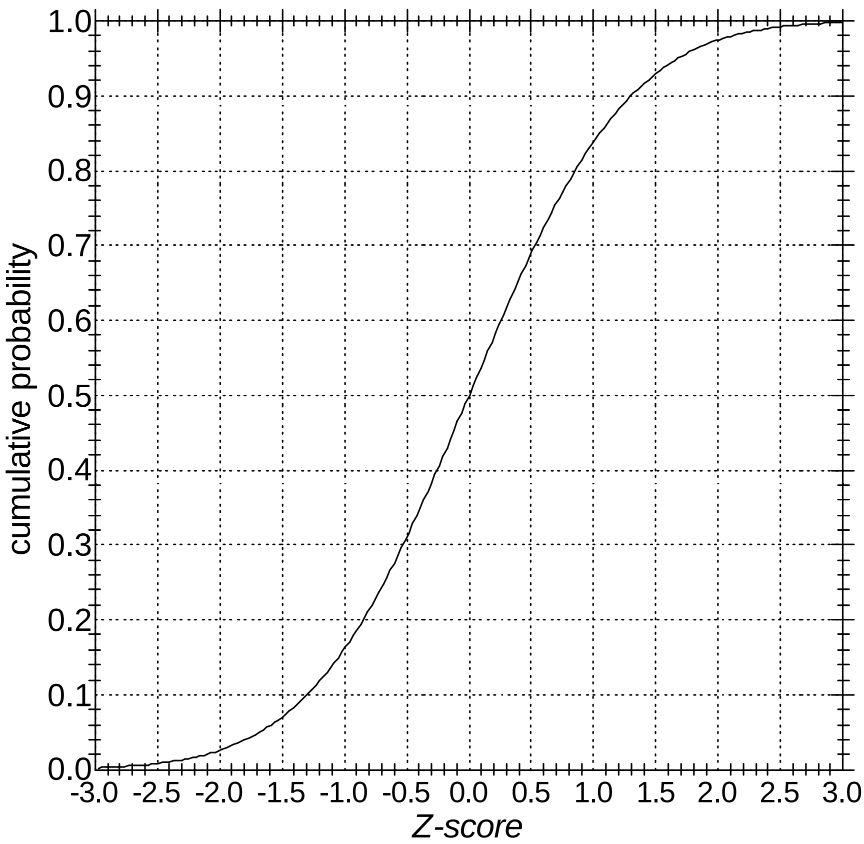

Figure 1. Cumulative probabilities for *Z*-scores applicable to the time series of average-stream indices from the Statistical Areas. This plot can be used to convert *Z-scores* to probabilities.

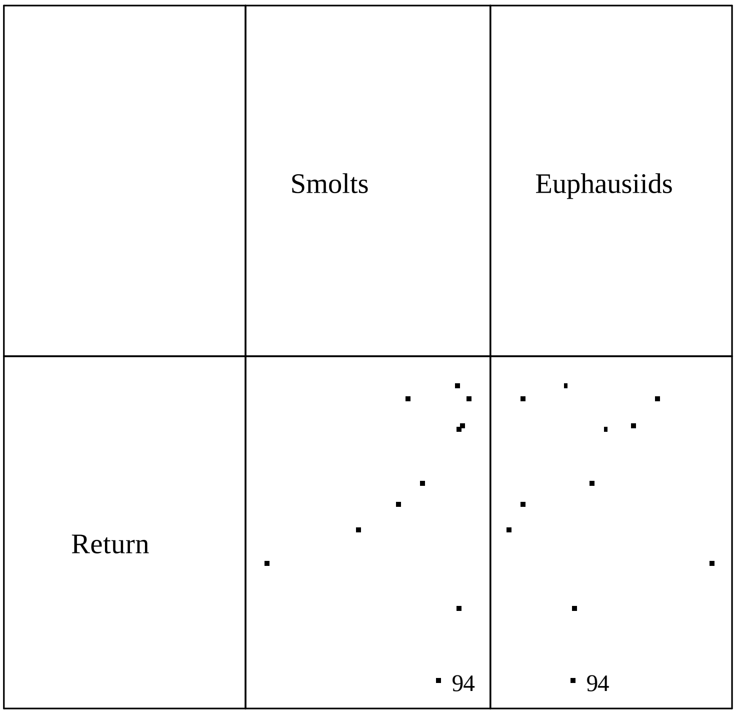

Figure 2. Scatter plots of the natural logarithms of number of Carnation Creek returning adults against number of Carnation Creek smolts and median abundance (no.• m^{-2}) of 9-12 *T. spinifera* over June – August of the first marine year. Numbers are return year.

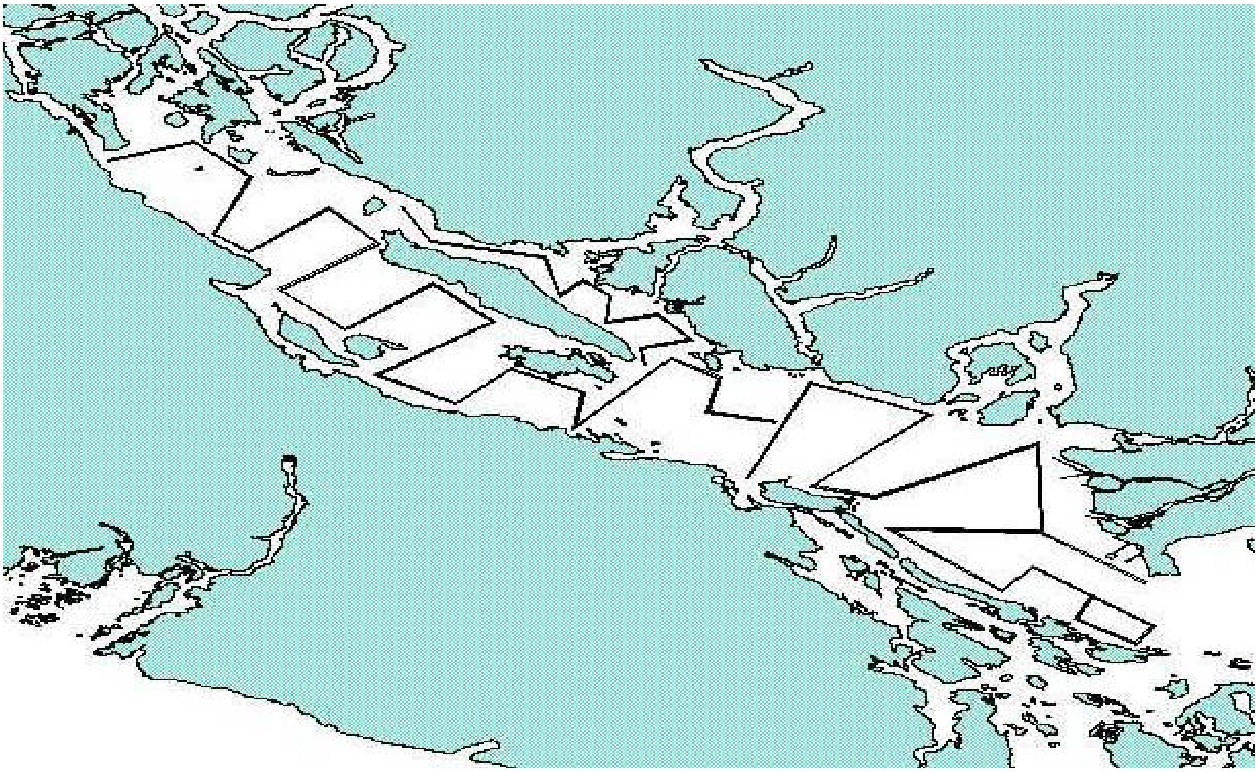

Figure 3. Survey track for annual trawl surveys in the Strait of Georgia, 1997 to 2002.

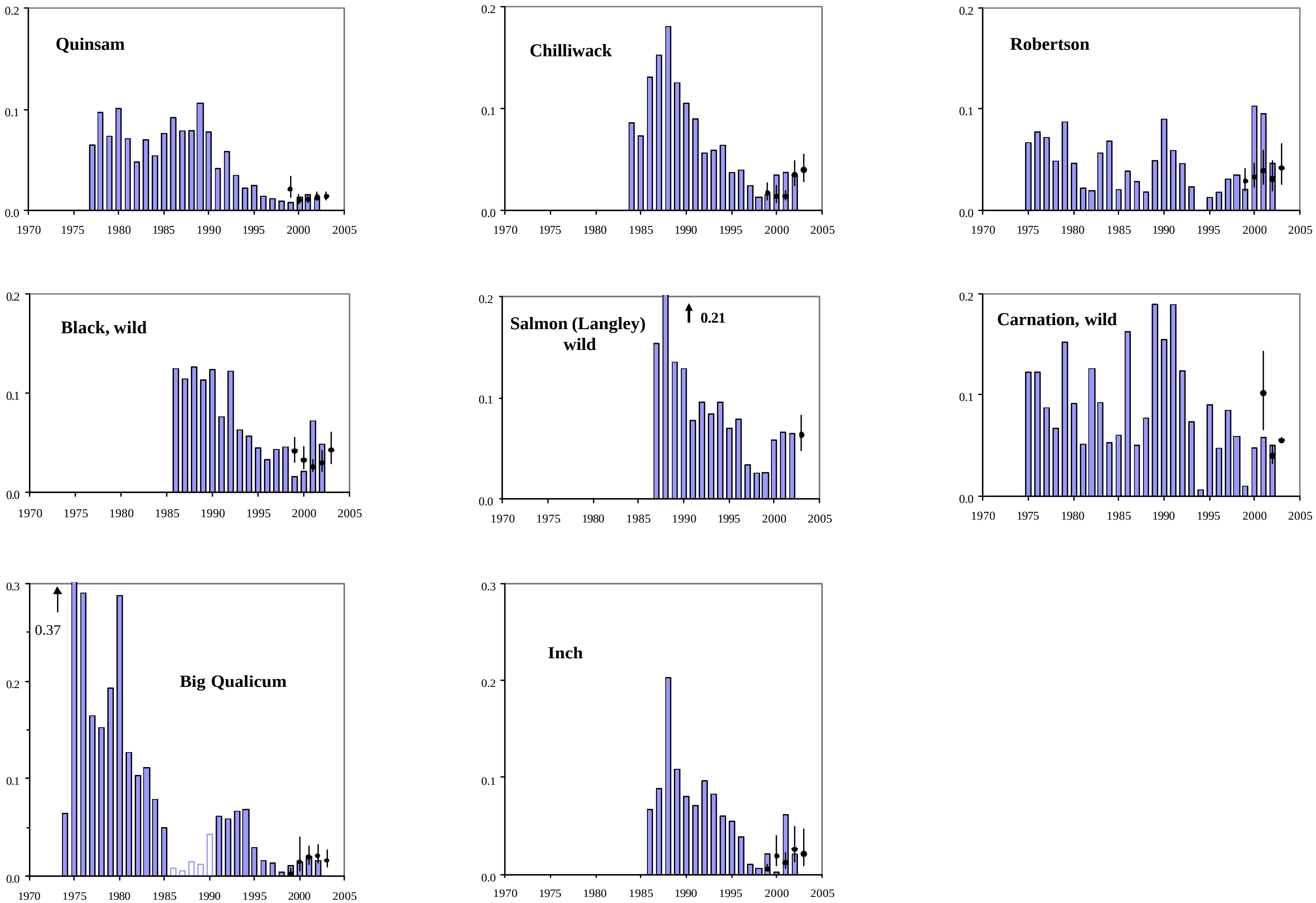

Figure 4. Marine survivals of southern BC coho since 1974. Indicator stocks are arranged in left to right columns for GBW, LowFr and WCVI, respectively. Forecasts since 1999 are shown as point symbols and bars, the latter indicating the 50% CL's. Open bars in the Big Qualicum graph indicate years when fish culture problems reduced smolt quality.

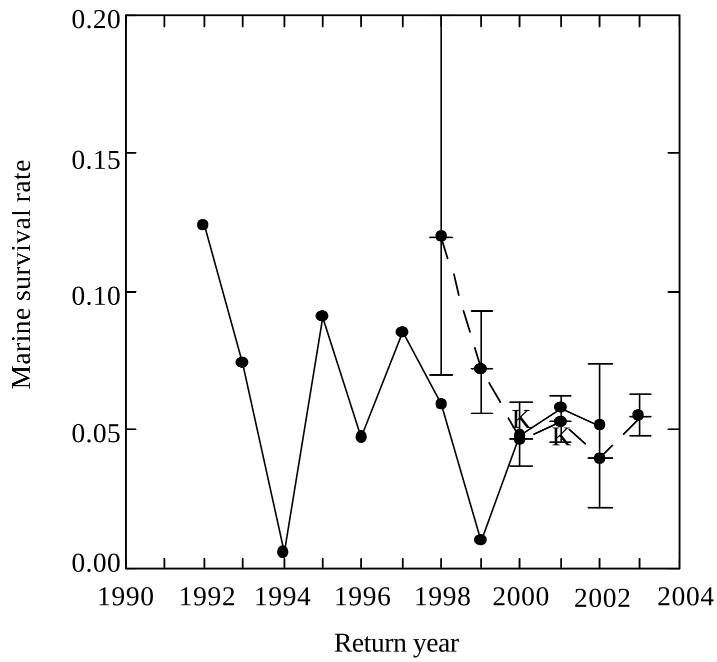

Figure 5. Results of retrospective analysis of forecasting accuracy of smolt-euphausiid regression for Carnation Creek coho. Solid line – observed survival rate. Dashed line – predicted survival rate. Error bars – 95% CL for the predicted value (Sokal and Rohlf 1995). K – observed marine survival rate for Kirby Creek coho.

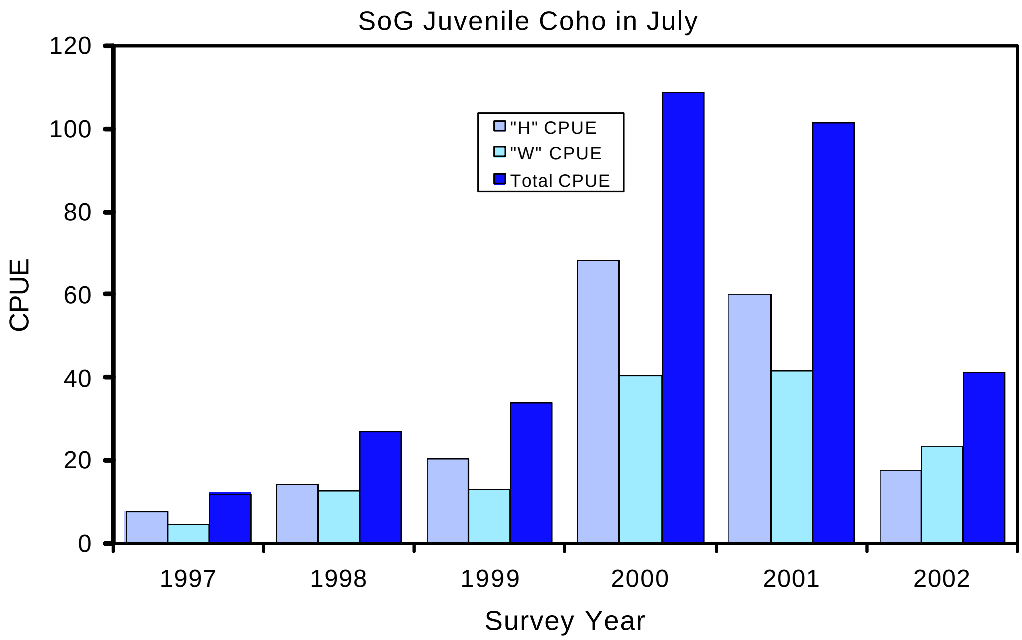

Figure 6. Catch per unit effort of marked and unmarked age x.0 coho in Strait of Georgia trawl surveys, 1997 to 2002. CPUE's are given for hatchery coho (Ad-clips, 'H') and unclipped coho ('W').

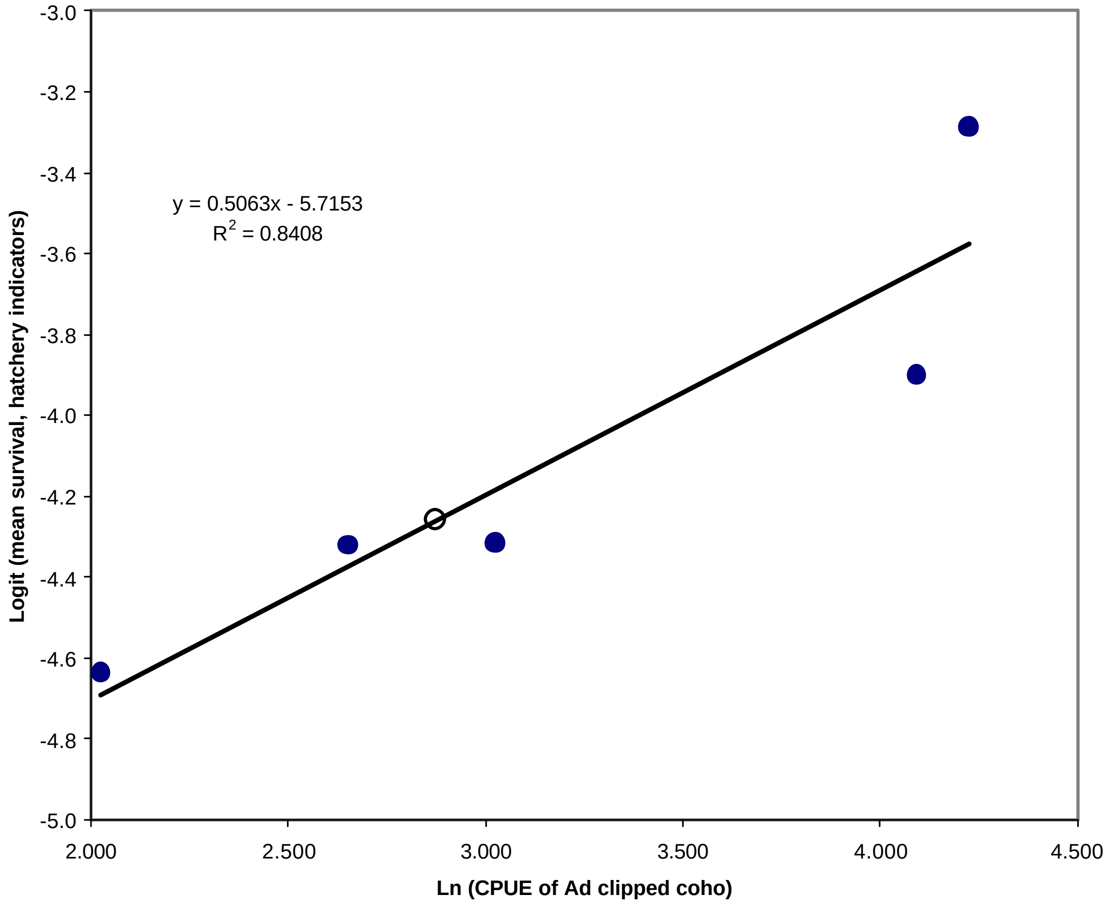

Figure 7. Regression of coho catches per hour (CPUE) in Strait of Georgia trawl surveys with mean survival of coho from Georgia Basin hatchery indicators: Chilliwack, Inch, Quinsam and Big Qualicum. The 2003 forecast is shown as an open circle and equates to a survival of 0.014.

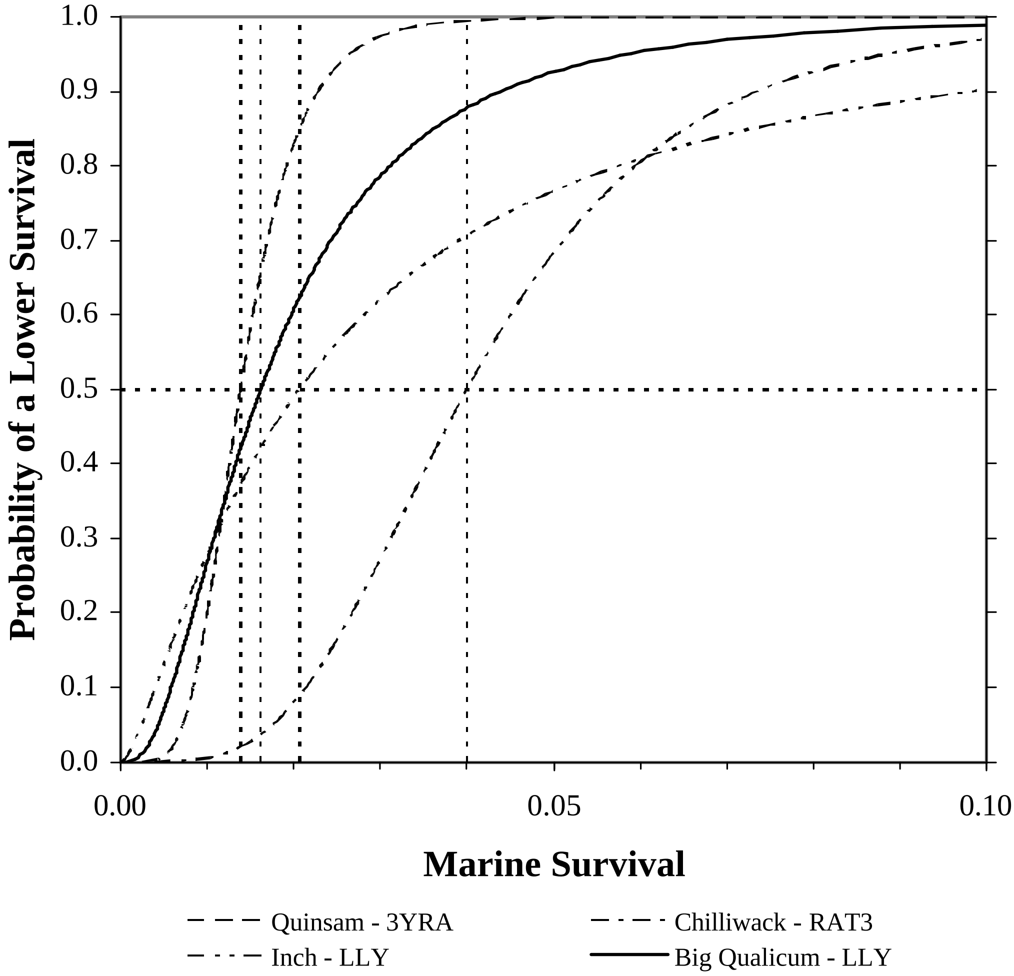

Figure 8. Cumulative probability distributions around the time-series forecasts of marine survivals in 2003 for four hatchery indicators in the Georgia Basin. All are the best forecast models for individual indicators.

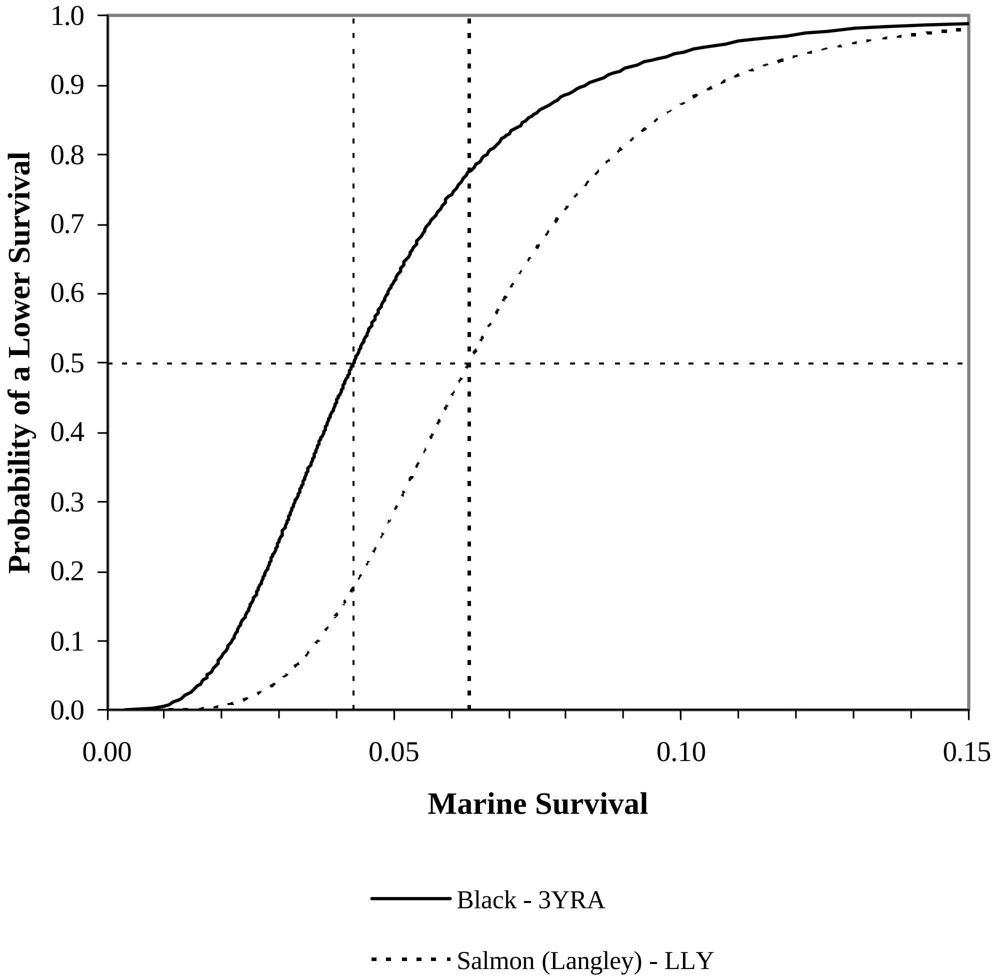

Figure 9. Cumulative probability distributions around the best available forecasts of marine survival in 2003 for two wild indicators in the Georgia Basin: Black Creek and Salmon River (Langley). Both are time-series forecasts.

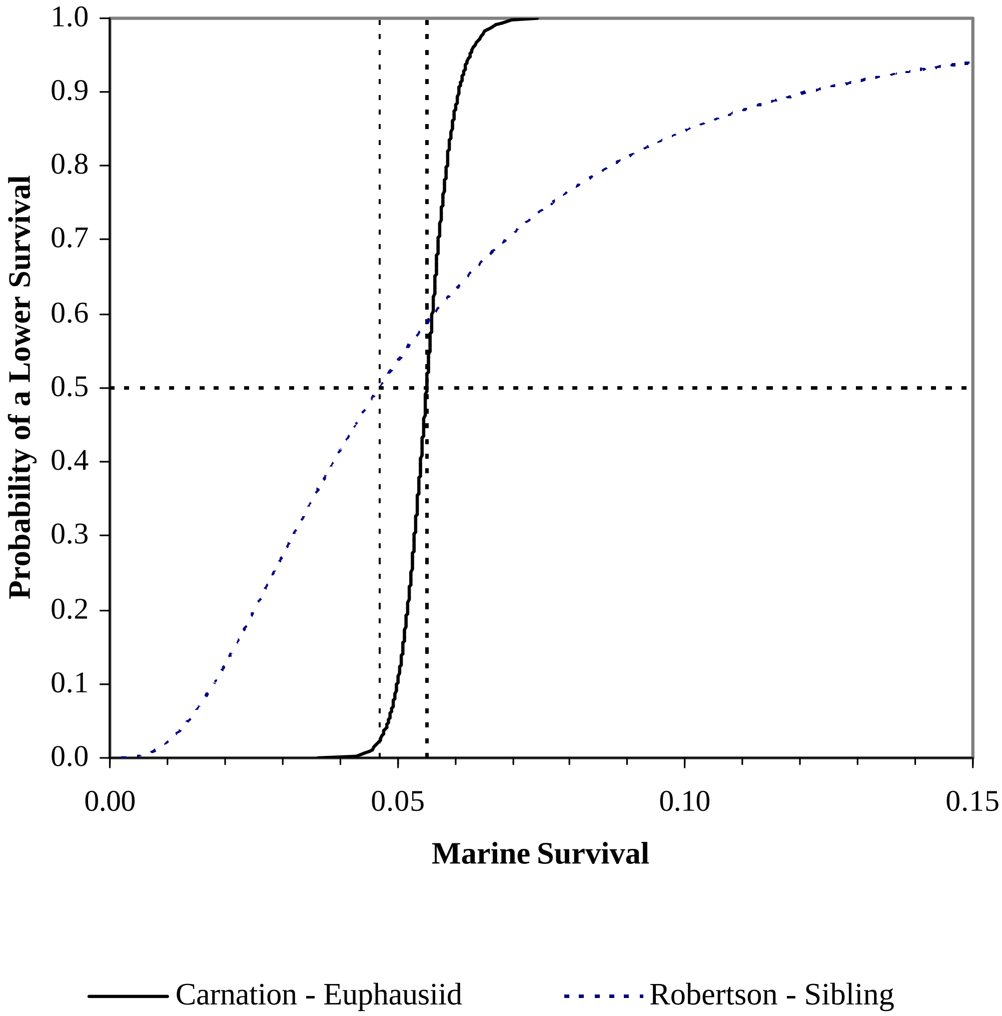

Figure 10. Cumulative probability distributions around the best model forecasts of survival to wVI indicators in 2003: Carnation Creek wild stock and Robertson Creek hatchery stock.

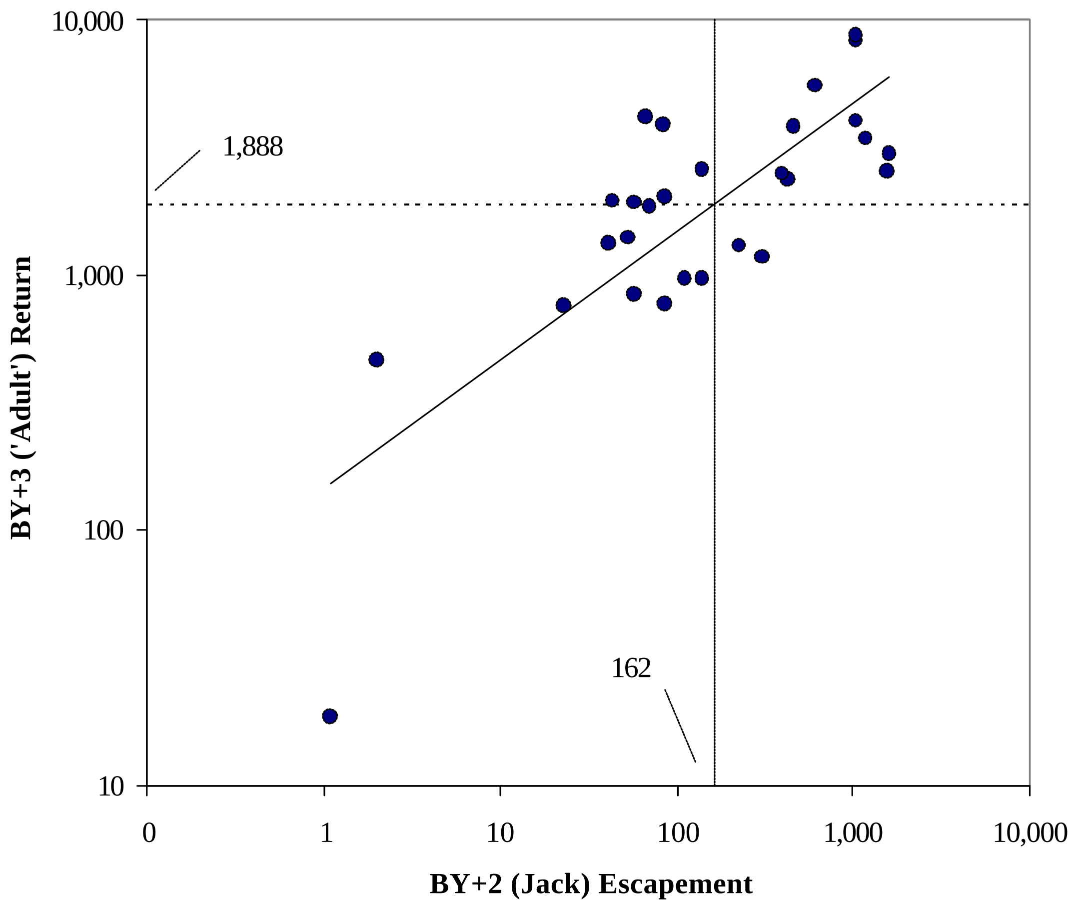

Figure 11. Sibling relationship for Robertson Creek Hatchery coho, showing the forecast adult return in 2003 of Ad-CWT coho, based on a 2002 escapement of 162 Ad/CWT jack coho. The 1,888 forecast return equates to a survival of 4.7%.

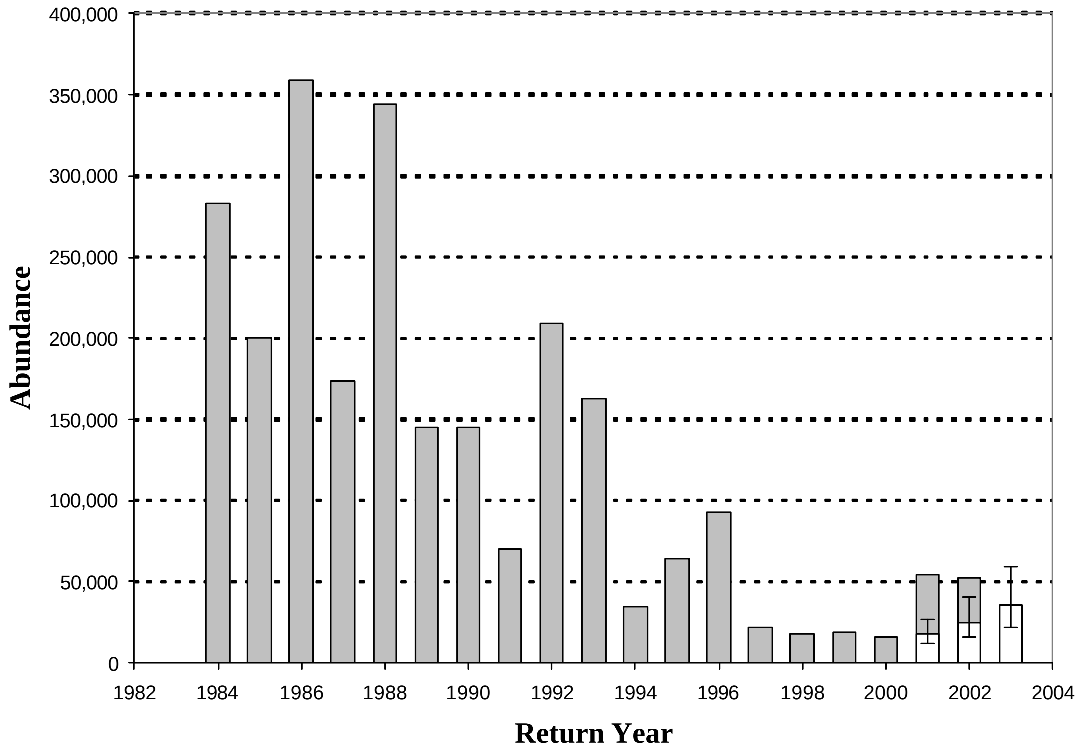

Figure 12. Estimated abundance of Thompson River watershed coho from 1984 to 2002. The forecasts for 2001 to 2003 are shown as clear bars with associated 50% CI's.

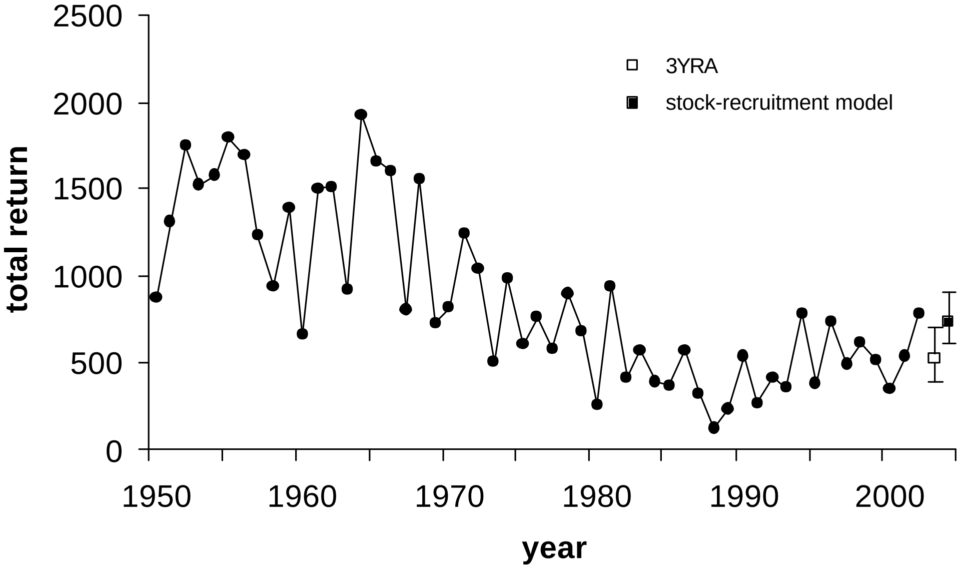

Figure 13. Total return to the average stream in Area 7. The S-R and 3YRA forecasts for 2003 with associated 50% CI are shown to the right of the graph. The 3YRA model is the preferred model.

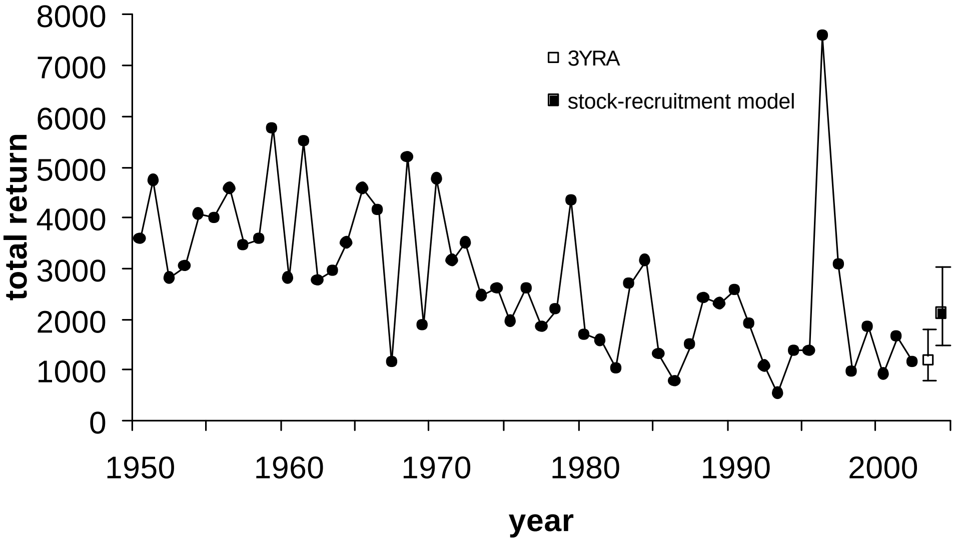

Figure 14. Total return to the average stream in Area 8. The S-R and 3YRA forecasts for 2003 with associated 50% CI are shown to the right of the graph. The 3YRA model is the preferred model.

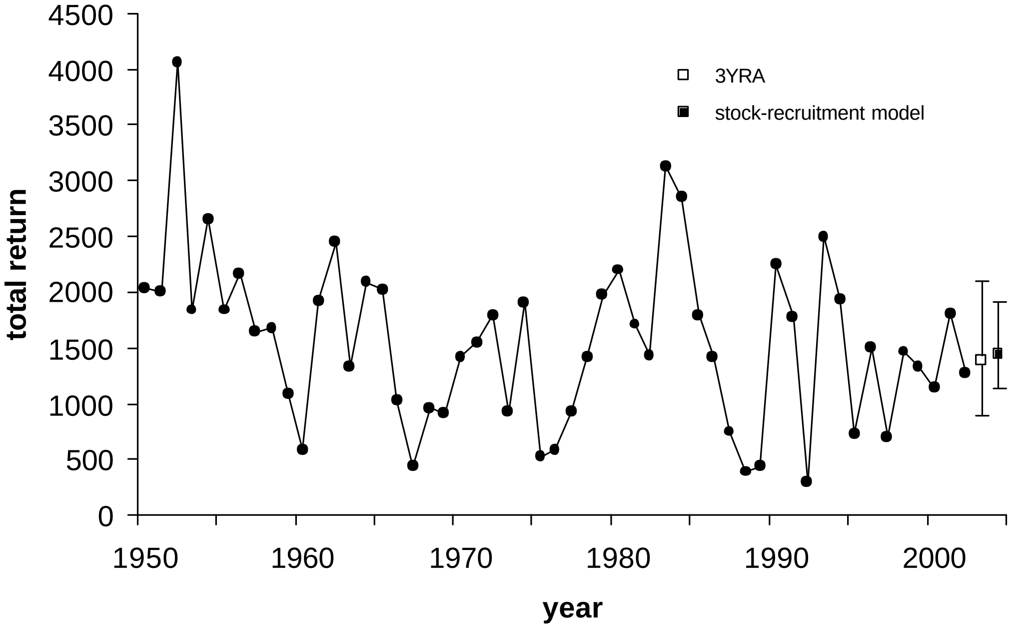

Figure 15. Total return to the average stream in Area 9 to 11. The S-R and 3YRA forecasts for 2003 with associated 50% CI are shown to the right of the graph. The 3YRA model is the preferred model.

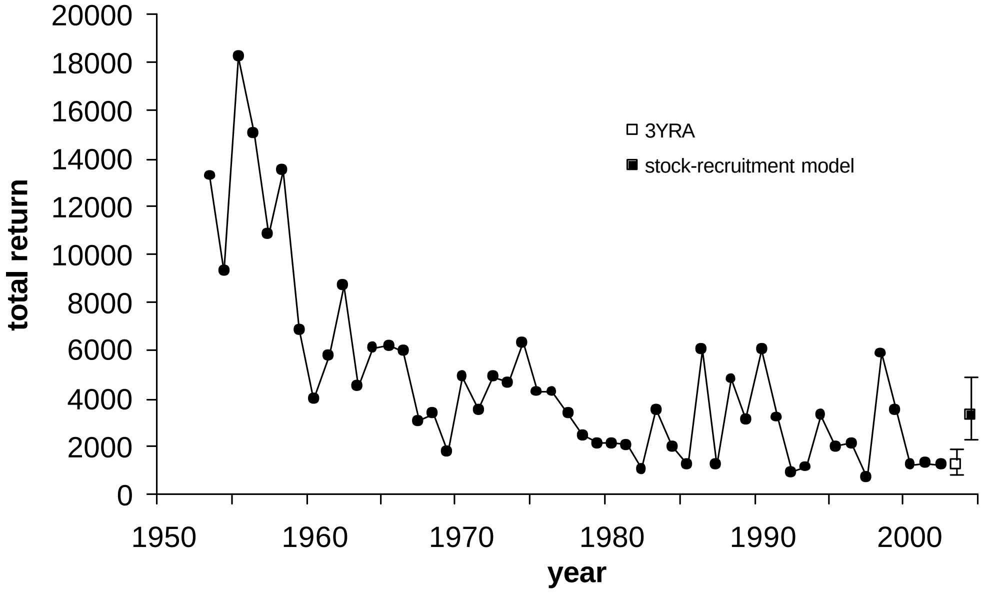

Figure 16. Total return to the average stream in Area 12. The S-R and 3YRA forecasts for 2003 with associated 50% CI are shown to the right of the graph. The 3YRA model is the preferred model.

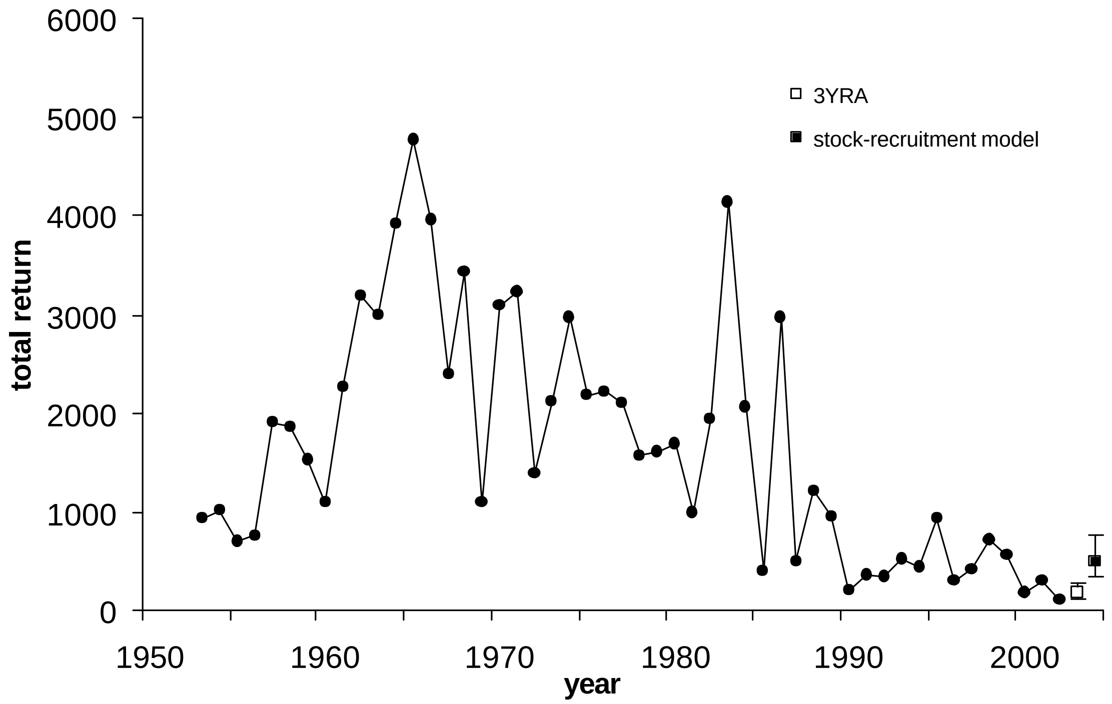

Figure 17. Total return to the average stream in Area 13. The S-R and 3YRA forecasts for 2003 with associated 50% CI are shown to the right of the graph. The 3YRA model is the preferred model.

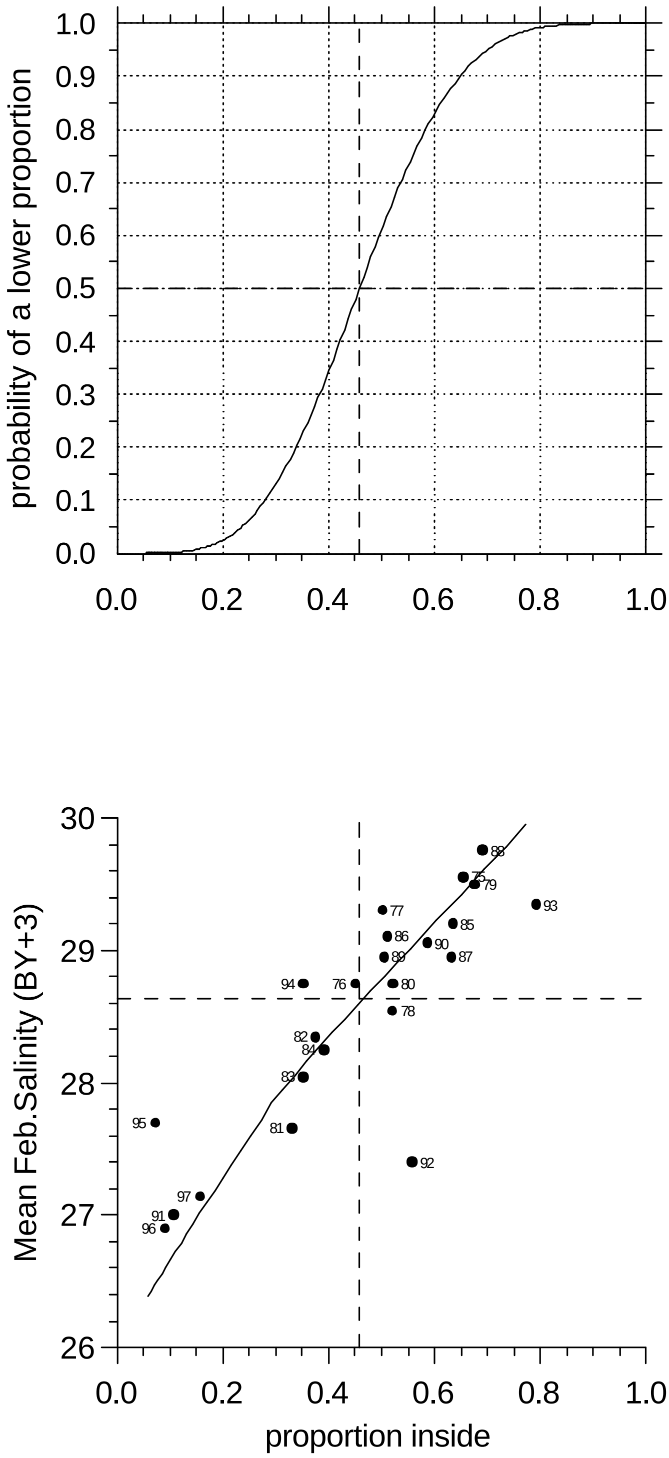

Figure 18 Predicting p_{inside} for 2003 using mean February salinities at Chrome and Sisters islands. The lower panel is the predictive relationship. The upper panel is the probability distribution for the point prediction.