Fisheries and Oceans Canada
Pêches et Océans Canada

Canadian Stock Assessment Secretariat
Research Document 99/186

Secrétariat canadien pour l'évaluation des stocks
Document de recherche 99/186

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Forecast for northern British Columbia coho salmon in 1999

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ISSN 1480-4883
Ottawa, 1999

Abstract

This paper documents forecasts of marine survival and abundance for the coho of northern British Columbia including the upper Skeena conservation area.

Marine survival:

Marine survival at the three northern indicators is expected to be above average for 1999.

indicator	model	$\hat{s}_{1999}$	(50% CI)
Lachmach	sibling regression	0.175	(0.143–0.215)
Toboggan Creek hatchery	from Lachmach	0.046	(0.028–0.075)
Fort Babine hatchery	from Lachmach	0.033	(0.014–0.076)

The forecast for Fort Babine is poorly defined. Based on three years observations the survival rate of wild Toboggan Creek coho should be 0.176, which is the same as the forecast for the Lachmach. We note though that survival rate forecasts for the Skeena were optimistic in 1998.

Abundance forecast:

After the application of stock-recruitment and time-series models to reconstructions of abundance in eight aggregates in northern B.C. we conclude the following about abundance in 1999:

aggregate	1999 abundance forecast	confidence in forecast
Babine Lake upper Skeena	well below average	high
lower and middle Skeena	below average	moderate
Area 3	below average	high
Area 5	below average	low
Area 6	well below average	low
Areas 7 & 8	below average	low

Average abundance was calculated over the period 1950 to 1998 for the Statistical Area aggregates and over the period 1946 to 1998 for Babine Lake. Abundance forecasts relative to this period are not necessarily indicative of aggregate status.

Abundance was not forecast for Area 9 (Rivers Inlet) and Area 10 (Smith Inlet). The escapement data for those areas in the 1990’s is insufficient to make a forecast. Escapement data in 1998 suggest that both areas are similar to Area 8. Abundance was not forecast for the Queen Charlotte Islands because of a lack of an exploitation rate time series.

We note that these forecasts were derived from the more conservative of the two approaches considered. Given that survival is forecast to be above average at least in the northern area, it is possible that our forecasts are in fact very conservative. It is probable however, that even with above average survival, that total abundance of the Babine Lake and upper Skeena aggregates will remain sufficiently low to warrant considerable caution in managing fisheries in 1999. It would be prudent to extend that caution to Areas 5 and 6.

Résumé

Le présent document de recherche traite des prévisions de survie en mer et de l'abondance du saumon coho du nord de la Colombie-Britannique, y compris la zone de conservation de la haute Skeena.

Survie en mer :

On prévoit que la survie en mer pour 1999, déterminée aux trois points repères du nord, sera supérieure à la moyenne.

Points repères	Modèles	$\hat{s}_{1999}$	(IC de 50 %)
Lachmach	Régression des espèces jumelles	0,175	(0,143–0,215)
Pisciculture de Toboggan Creek	A partir de Lachmach	0,046	(0,028–0,075)
Pisciculture de Fort Babine	A partir de Lachmach	0,033	(0,014–0,076)

La prévision pour Fort Babine est mal définie. En se fondant sur trois années d'observations, le taux de survie pour les cohos sauvages de Toboggan Creek devrait être de 0,176, soit la même valeur prévue que pour Lachmach. Il est à noter que les taux de survie prévus pour la Skeena en 1998 étaient optimistes.

Prévision d'abondance :

L'application de modèles stock-recrutement et de séries chronologiques aux reconstructions de l'abondance de huit concentrations du nord de la C.-B. nous a permis de tirer les conclusions suivantes pour 1999:

Concentrations	Abondance prévue pour 1999	Niveau de confiance en la prévision
lac Babine haute Skeena	Bien en deçà de la moyenne	élevé
bas et centre de la Skeena	En deçà de la moyenne	moyen
zone 3	En deçà de la moyenne	élevé
zone 5	En deçà de la moyenne	faible
zone 6	Bien en deçà de la moyenne	faible
zones 7 et 8	En deçà de la moyenne	faible

L'abondance moyenne a été calculée pour les concentrations de la zone statistique, de 1950 à 1998, et pour le lac Babine, de 1946 à 1998. Les prévisions d'abondance pour cette période ne reflètent pas nécessairement l'état des concentrations.

Il n'a pas été fait de prévision de l'abondance pour la zone 9 (Rivers Inlet) et la zone 10 (Smith Inlet). Les données sur les échappées pour ces zones pour les années 1990 ne sont pas suffisantes pour établir une révision. Les données sur les échappées de 1998 portent à croire que ces deux zones sont semblables à la zone 8. Étant donné l'absence de série chronologique des taux d'exploitation, il n'y a pas eu de prévision d'abondance pour les îles de la Reine-Charlotte.

Nous signalons que ces prévisions ont été obtenues à l'aide de la plus prudente des deux méthodes considérées. Comme la survie prévue est supérieure à la moyenne dans, au moins, la zone nord, il est possible que nos prévisions soient, au fait, très conservatrices. Il est cependant probable que, même avec un taux de survie supérieur à la moyenne, l'abondance totale des concentrations du lac Babine et de la haute Skeena demeure suffisamment faible pour justifier une grande prudence pour la gestion des pêches de 1999. Il y aurait aussi lieu de faire preuve de prudence pour les zones 5 et 6.

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1. Introduction

In this paper we detail:

1. A forecast of marine survival and total return for Lachmach River (Area 3; Work Channel) coho;
2. Forecasts of marine survival for Toboggan Creek and Fort Babine hatchery indicators (Area 4; upper Skeena conservation area);
3. Forecasts of the total return and escapement of the Babine Lake (Area 4; upper Skeena conservation area) coho aggregate; and
4. Forecasts of indices of total return to the coho of the Nass (Area 3); the lower Skeena (Area 4 lower); the upper Skeena (Area 4 upper); Kitimat (Area 6); and Areas 7 and 8 on the Central Coast.

For all but the Lachmach and the two hatchery indicators in the Skeena, these forecasts are the first formal forecasts made for northern BC coho stocks.

2. Data Sources

Catches and escapement data for coded-wire tagged coho from the Lachmach River (wild indicator) and Toboggan Creek and Fort Babine hatchery indicators were obtained from the Mark Recovery Program database maintained at the Pacific Biological Station in Nanaimo, B.C. CWT recovery data for 1998 are preliminary and may change as catch and escapement estimates are finalized. Escapement data for Lachmach River coho were obtained from program sources in the Stock Assessment Division. Visual escapement estimates for streams in Areas 1 to 10 were obtained from a database maintained by the Stock Assessment Division in the Prince Rupert Office. (BS, DFO, Prince Rupert). Escapement data for the Babine Lake coho aggregate were obtained from a database maintained by the Stock Assessment Division in the Prince Rupert Office. (pers. comm. M. Jakubowski, DFO, Prince Rupert). Escapement data for Toboggan hatchery and wild coho were obtained from the Toboggan Creek Enhancement Society (pers. comm. M. O'Neill, TCES, Smithers). All data from 1998 should be considered preliminary and subject to revision as escapement estimates are finalized.

Coho could not be retained in Canadian waters in 1998 as part of the conservation measures undertaken to protect upper Skeena coho. There were some exceptions in terminal areas where surpluses were identified. Where there were fisheries, coho that were caught were released with minimal harm. Estimates of the effective exploitation rate have been made for northern BC and will be presented in an upcoming PSARC Working Paper. Estimates of the exploitation rate in Canadian waters range between 2% and 5%.

Many of the analyses presented in this Working Paper use reconstructed time series of exploitation rate on Skeena coho. These reconstructions are derived from gear, area and time stratified effort for the period 1965 to 1987, when CWT estimates became available. The reconstructions are part of a comprehensive assessment of coho in the northern boundary area and will be summarized elsewhere (unpubl. data, Northern Boundary Technical Committee of the Pacific Salmon Commission, Vancouver, BC.)

3. Forecasting Models and Retrospective Analysis of Predictive Power.

3.1 Forecasting models

We use three approaches to forecasting in the Working Paper. Where there are time-series longer than about 15 years we use four quasi time-series models. In each model the variable being forecast (v_t) is first transformed so that

$$Z_t = \Im(v_t) \tag{1}$$

The Log transformation was used for abundance. The Logit transformation[1] was applied to proportions such as survival (*s*). The four models can then be described as follows:

mnemonic	model	Equation
LLY ("Like Last Year")	$Z_{t+1} = Z_t + \varepsilon_t$	(2)
3YRA (3-year average)	$Z_{t+1} = \frac{\sum_{k=t-2,t} Z_k}{3} + \varepsilon_t$	(3)
RAT1 (1 year trend)	$Z_{t+1} = \frac{Z_t^2}{Z_{t-1}} + \varepsilon_t$	(4)
RAT3 (average 3-year trend)	$Z_{t+1} = \frac{\sum_{k=t-2,t} Z_k / Z_{k-1}}{3} Z_t + \varepsilon_t$	(5)

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

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

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

		years used in prediction	
		1	3 (≈ 1 cycle)
project trends?	NO	LLY	3YRA
	YES	RAT1	RAT3

For Lachmach River coho the marine survival rate was predicted using a "sibling-regression" model, where the total return of age-n.1[2] fish ($A_{n.1}$) is predicted from the observed age-n.0 escapement of males ($E_{n.0}$, 'jacks'):

$$\log_e A_{n.1} = b \log_e E_{n.0} + a \tag{6}$$

Survival (s_{smolt}) was then calculated by dividing the age-n.1 return in year t by the number of smolts counted out of the system in year t-1 (N_{smolt}).

All of the approximately 25 coho populations spawning above the Babine River counting fish have been combined into the Babine Lake aggregate. For these coho we have estimates of total escapement from 1946 to 1998. The fence was not operated in 1964. The 1964 escapement in that year was estimated from the Skeena test-fishery index using an iterative contingency-table algorithm (Brown 1974) implemented in Excel®[3] (pers. comm. J. Blick, ADFG, Juneau, AK). Estimates of age composition of returning adults exist for 15 years in the 1970's and 1980's. Age composition in the escapement is significantly related to spawner numbers in the brood year. We used that relationship to estimate age composition in years for which there were no data. Using the reconstructed exploitation rate time-series we then estimated total recruitment and did a standard Ricker stock-recruitment analysis (Hilborn and Walters 1992). Recruitment in 1999 was forecast with the escapement observed in 1996.

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. For example, of the 51 streams surveyed at some point between 1950 and 1998 in the upper Skeena (Area 4), there is only one system where there are counts in more than 80% of the years (Babine aggregate) and only seven with counts in at least half of the years. Nevertheless, we think that the time series do contain information about escapement trends in each area.

[2] The age designation follows the European convention, which is "number of FW winters**.**number of ocean winters". In most northern coho escapement and catch is made up of a mixture of age 1.1 and age 2.1 adults with some age 3.1 animals.
[3] Registered trade-mark of Microsoft Corp., Redmond, WA. Mention of this product does not constitute endorsement.

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

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

Then the $p_{i,t}$ were averaged across all streams i within each year t to give a time series $p_{\bar{i},t}$ or 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 the streams of all of the 10 Statistical Areas. The Skeena (Area 4) was divided into the upper and lower/middle areas. The upper Skeena encompasses the Bulkley/Morice and all streams upstream of its confluence with the Skeena, with the exception of the Kispiox, which was included with the middle Skeena.

In Areas 5 and 7 no streams were surveyed in 1995 and 1996. We used a contingency table fill-in to estimate values of $p_{\max}$ in both areas. In Area 5 time series of $p_{\max}$ Areas 4L and 6 were used. In Area 7 time series of $p_{\max}$ in Areas 6 and 8 were used. These estimated values have little influence on stock-recruitment analysis but in both areas the estimated total return for 1996 is incorporated into the 3YRA forecast, further increasing the uncertainty in those forecasts.

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 and Central Coast areas have very similar ocean distributions (Anon. 1994) from which we concluded that the temporal patterns in ocean exploitation rates are likely similar between all of the sites in the North and Central Coast. We also know from patterns of CWT recoveries that fish from the lower and middle Skeena are more similar to coho from the more southerly Areas, while fish from the Babine have similar distributions to Area 3 coho. We therefore assumed that the exploitation rate time series developed for Babine coho was applicable to Area 3 coho, while the time series developed for Toboggan Creek was applicable to the remaining areas. In both instances the FW components of those exploitation time series were removed before application to the other areas. Coho from QCI have a different ocean distribution and, we presume, a different exploitation rate. We have no CWT data from Areas 9 and 10, and so don't know where coho from those areas are distributed. Consequently, no attempts to reconstruct abundance were made for coho of the three aggregates in the Queen Charlotte Islands, or the Area 9 or Area 10 aggregates.

Forecasts for these large aggregates were then 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 1999 using observed spawner indices in 1996. There was insufficient time to do a retrospective comparison between the two approaches, but a retrospective comparison between the four time series models was done.

3.2 Retrospective analyses

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

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

and the Mean Absolute Deviation (*MAD*):

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

Note that this calculation is performed in the variable space and not in the transformed (equation 1) space. Retrospective analyses were used only to select the best performer from among the four time-series models.

4. Marine Survival Estimates

4.1 1998 Forecasts compared to 1998 observed survivals

Holtby and Finnegan (1997) forecast marine survival rates for the Lachmach wild indicator and for the Toboggan Creek and Fort Babine indicators. An indirect forecast was also provided for the wild component of the Toboggan Creek population, which was based on a very short series of observations on the ratio between hatchery and wild survival at Toboggan. As the following Table shows survivals were lower than predicted at all three sites in the Skeena. Survival of Toboggan Creek hatchery coho was 70% of the forecast or about the 22%ile. Survival at Fort Babine was 40% of the forecast or about the 12%ile. Survival of the Lachmach River wild coho as slightly greater than the forecast of 0.09 and was about the 56%ile.

indicator	forecasting model	$\hat{s}_{1998}$	5%–10%–25% CI lower boundary	s_{1998}
Lachmach River	sibling regression	0.091	0.056–0.064–0.076	0.096
Toboggan Creek	regression on Lachmach survival	0.020	0.007–0.010–0.014	0.014
Toboggan Creek (wild)	observed scalar from hatchery survival	0.090	none given	0.056
Fort Babine	regression on Lachmach survival	0.015	0.003–0.005–0.010	0.006

4.2 Marine Survival Rate Forecast

Marine survival data for the three northern indicators are given in Table 1. The forecast for the total return of Lachmach coho was made with the following sibling regression:

$$\log(A_{n.1}) = 5.6239 + 0.4360\log(E_{n.0})$$

$$(N = 10;\ \text{adj. } r^2 = 0.642;\ P < 0.005)$$

The estimated jack escapement ($E_{n.0}$) in 1998 to Lachmach was 425, which leads to a forecast total return of 3,877. The average total return at Lachmach is 2,912 (standard deviation: 2,545). The Z-score of the 1999 forecast abundance is 0.80, which is moderately above average. The 1998 smolt run at Lachmach was 22,097 leading to a marine survival forecast of 0.175. The confidence intervals for the Lachmach survival and abundance forecasts are detailed in Table 2 and in Figure 1.

Very few or no jacks return to interior sites so no sibling regression is possible for either Babine or Toboggan Creek. However, the temporal patterns in marine survival are similar for the three northern indicators (Figure 2), allowing us to use the Lachmach forecast to forecast survivals in the Skeena indicators. The relationship between Lachmach and Toboggan survivals:

$$\text{logit}(s_{Toboggan}) = 0.7054\,\text{logit}(s_{Lachmach}) - 1.9436$$

$$(N = 11;\ \text{adj. } r^2 = 0.21;\ P = 0.09)$$

is marginally significant and gives a forecast survival at Toboggan of 0.046 (Table 2; Figure 2). That survival is above average, although the dataset is quite short.

The wild smolt output from Toboggan Creek in 1998 was 66,565 (BF, unpubl. data; SKR Consultants Ltd. 1998). The estimate is based on the observed hatchery to wild ratio in smolts captured near the confluence of Toboggan Creek and the Bulkley River. All hatchery smolts are externally marked (Ad-clip). In 1998, a rotary screw trapped was used for the first time. In previous years a floating fyke trap had been used. Even though the amount of water screened by the rotary screw and fyke traps is similar the trapping efficiency of the rotary screw trap would appear to be less than that of the fyke. If the rotary trap was relatively more efficient in capturing hatchery smolts that wild ones then the estimate of wild smolts would be biased high. The estimate in 1998 was also done under difficult flow conditions. For these reasons we suspect the estimate to be of low precision. The estimate of wild smolt production in 1998 is also substantially above the three previous estimates (see following Table). From smolt enumeration done in 1995 to 1997 (Saimoto 1995; SKR Consultants 1996, 1997) and a comparison of marked and unmarked returns to Toboggan Creek, three estimates of the survival differential between wild and hatchery smolts are available for Toboggan Creek coho.

smolt year	estimated wild smolt number	ratio of wild to hatchery marine survival	estimated wild survival
1995	38,137	3.8855	0.097
1996	34,989	3.9663	0.020
1997	42,429	3.6110	0.067
1998	66,565	–	–

Using these observations wild survival of Toboggan Creek coho could be 0.176 in 1999 and the total return could be 11,700 (Z-score = 2.84). Such a return would be well above average and would lead to an escapement of more than 8,000 animals in the absence of Canadian fisheries. However, the 1997 fry densities did not indicate such a large smolt production[4]. If smolt production was average then the forecast wild return would be 6,770 (Z-score = 0.91) with an anticipated escapement of around 4,800. These values are above average and in a relative sense are comparable to those forecast for Lachmach.

The same relationship for Fort Babine is much weaker largely because of the smaller dataset and lower than expected survival for the 1995 brood year (Table 1). The predictive relationship is

$$\text{logit}(s_{Babine}) = 1.174\,\text{logit}(s_{Lachmach}) - 1.549$$

(N = 5; adj. r^2 = 0.17; P = 0.27)

The forecast survival for Babine coho is 0.033 (Table 2; Figure 2). However, other than suggesting that survival will be above average, this prediction is not useful because its confidence interval is so broad.

5. Forecasts of abundance and escapement

Forecasts of abundance for the Babine Lake aggregate and for the average-stream index in the upper Skeena (Area 4), the lower and middle Skeena (Area 4), the Nass (Area 3), the Principe/Grenville Channel (Area 5), the Kitimat region (Area 6), the Bella Bella region (Area 7) and the Bella Coola region (Area 8) were made following the same procedures, and are considered together in this section. The following Table summarizes the organization of data and forecast Tables and Figures. The Figures show the time series of total returns (Babine) or total return index (all other Areas) with 3YRA forecasts for 1999.

aggregate	data Table	forecast summary Table	relevant Figures
Babine Lake aggregate	Table 3	Table 15	Figure 3 to Figure 5
upper Skeena	Table 4	Table 16	Figure 6
lower and middle Skeena	Table 5	Table 17	Figure 7
Nass (Area 3)	Table 6	Table 18	Figure 8
Principe/Grenville (Area 5)	Table 7	Table 19	Figure 9
Kitimat (Area 6)	Table 8	Table 20	Figure 10

[4] Modeled smolt output was 712 smolts/km or about 15,000 total smolts.

aggregate	data Table	forecast summary Table	relevant Figures
Bella Bella (Area 7)	Table 9	Table 21	Figure 11
Bella Coola (Area 8)	Table 10	Table 22	Figure 12
Central Coast (Areas 9 & 10)	Table 11	no forecast given	Figure 13
Queen Charlotte Islands (Areas 1, 2W and 2E)	Table 12	no forecast given	Figure 14

Table 13 summarizes the results of the Ricker stock-recruitment model fits for the six coho aggregates. The only notable anomaly in these model fits was in the upper Skeena aggregate. In 1979, the escapement index for this aggregate was very low. This produced unusually low and high values of R/S in the 1976 and 1982 respectively, and all three years were dropped from the analysis. The 3YRA model outperformed the LLY model and both ratio models (RAT1 and RAT3) for all of the aggregates. Only forecasts from the 3YRA model are shown.

Table 14 summarizes the results of abundance forecasting for nBC coho aggregates. For all eight aggregates there are two abundance forecasts, one based on a stock-recruitment analysis and the other from a time-series model.

For all of the aggregates the forecast of 1999 abundance derived from the stock-recruitment analysis is larger than the one given by the time-series model, although the differences are small in two of the Areas. For aggregates that we believed are severely depressed (Babine, upper Skeena, and Area 6) the differences between the two forecasts are particularly large. To some extent the differences result from the recruitment failure seen in the 1997 escapement because the low abundance in 1997 is one of three years in the 3YRA forecast.

Abundance forecasts for the Babine, the upper Skeena aggregate and the Area 6 aggregate are for below-average returns (preceding Table). In the Babine and Area 6 the stock-recruitment forecast is for total abundance similar to those observed in 1998. For the upper Skeena aggregate the stock-recruitment forecast is about 50% of the abundance in 1998. The 3YRA forecasts for these three aggregates range between 41% and 55% of the stock-recruitment forecasts. In terms of time-series averages the stock-recruitment forecasts lie approximately between the 15%ile[5] and 25%ile while the time-series forecasts lie between the 5%ile and 10%ile. We conclude that the abundance of these aggregates will remain well below average in 1999.

The abundance forecast for the lower and middle Skeena aggregate is for a moderately below average return. Forecast abundance for the other aggregates is very similar – all are expected to be below average (Table 14). The Lachmach River indicator stream is in Area 3. The difference between the forecast for the Lachmach (above average abundance) and the Area 3 aggregate (slightly below average) is likely due to the very different time frames over which comparisons are possible. The forecasts of abundance in 1999 derived from the visual counts are judged against the average return between 1950 and 1998. Consequently, a forecast return that is below average does not necessarily imply that the aggregate is "depressed". Furthermore, the above average return forecast to Lachmach does not imply that the Lachmach stock is not currently depressed.

Forecasts of escapement are dependent not only on forecast abundance but also on exploitation rate. Alaskan exploitation rates ranged between 30% and 60% on Skeena CWT groups in 1998 and were largely unchanged from immediate past years. Alaskan exploitation rates are likely to remain the same in 1999. Therefore, at most 70% or as little as 40% of forecast abundance would be available for escapement in the absence of Canadian fisheries.

Both forecasting approaches use the same reconstructed data series. In general, we have the greatest confidence in forecasts where we have an indicator stock (Area 3, the Babine aggregate and the upper Skeena) and the least confidence in the forecasts for aggregates furthest removed from the indicators used to generate the exploitation rate time series (Areas 7 and 8). Because the time series forecast includes the effect of the very poor escapement and return in 1997, they tend to be more conservative than the stock-recruitment forecast, which do not. The forecasts must also be given in the context of the marine survival forecast for the Lachmach, which was for well above average survival (0.175). If survivals were generally higher throughout the north, and provided that smolt output was not severely depressed, then we would suspect that the 3YRA forecasts of abundance would generally be underestimates.

6. Conclusions

6.1 Marine survival

Marine survival at the three northern indicators is expected to be above average for 1999.

indicator	model	$\hat{s}_{1999}$	(50% CI)
Lachmach	sibling regression	0.175	(0.143–0.215)
Toboggan Creek hatchery	from Lachmach	0.046	(0.028–0.075)
Fort Babine hatchery	from Lachmach	0.033	(0.014–0.076)

The forecast for Fort Babine is poorly defined. The survival rate of wild Toboggan Creek coho should be 0.176, which is the same as the forecast for the Lachmach, but this prediction is based on very limited data. We note though that survival rate forecasts for the Skeena were optimistic in 1998.

6.2 Abundance forecast

The forecast total return of Lachmach coho is 3,877, which is above average (*Z*-score = 0.80). A low precision estimate of wild smolt output at Toboggan in 1998 was 66,565 suggesting that the total return of wild Toboggan coho will be 11,700, which is also above average.

[5] The proportion of observations that are expected to be smaller.

After the application of stock-recruitment and time-series models to reconstructions of abundance in eight aggregate stocks in north coastal British Columbia we conclude the following about abundance in 1999:

aggregate	1999 abundance forecast	confidence in forecast
Babine Lake upper Skeena	well below average	high
lower and middle Skeena	below average	moderate
Area 3	below average	high
Area 5	below average	low
Area 6	well below average	low
Areas 7 & 8	below average	low

We note that these forecasts were derived from the more conservative of the two approaches considered. Given that survival is forecast to be above average at least in the northern area, it is possible that our forecasts are in fact very conservative. It is probable however, that even with above average survival, that total abundance of the Babine Lake and upper Skeena aggregates will remain sufficiently low to warrant considerable caution in managing fisheries in 1999. It would be prudent to extend that caution to Areas 5 and 6.

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Table 1. Marine survival rate estimates at three northern BC coho indicators. Toboggan and Fort Babine are hatchery indicators. Lachmach is a wild indicator.

	marine survival rates		
return year	Lachmach	Toboggan	Fort Babine
1988	0.0301	0.0210	
1989	0.0440	0.0272	
1990	0.1130	0.0410	
1991	0.1210	0.0601	
1992	0.0880	0.0168	
1993	0.0610	0.0282	
1994	0.1740	0.0600	0.0400
1995	0.0820	0.0179	0.0103
1996	0.0720	0.0250	0.0314
1997	0.0550	0.0050	0.0055
1998	0.0960	0.0184	0.0065

Table 2. Forecasts of marine survival for three northern BC coho indicators and abundance for the Lachmach River, with associated confidence intervals.

	Lachmach		Toboggan	Fort Babine
probability of smaller return or survival	$\hat{A}_{1999}$	$\hat{s}_{1999}$		
99%	8871	0.401	0.281	0.862
95%	6593	0.298	0.158	0.337
90%	5782	0.262	0.118	0.184
75%	4748	0.215	0.075	0.076
50%	**3877**	**0.175**	**0.046**	**0.033**
25%	3166	0.143	0.028	0.014
10%	2600	0.118	0.017	0.005
5%	2280	0.103	0.012	0.002
1%	1694	0.077	0.006	0.0002

Table 3. Stock-recruit data for the Babine coho aggregate.

brood year	total escapement	exploitation rate	proportion age 3	R/S
1946	13411	0.547	0.62	1.907
1947	10815	0.547	0.62	2.436
1948	13734	0.547	0.62	1.659
1949	12961	0.547	0.52	1.524
1950	11654	0.547	0.59	0.948
1951	2276	0.547	0.51	6.436
1952	10554	0.547	0.53	1.895
1953	7655	0.547	0.57	2.180
1954	3359	0.547	0.80	4.383
1955	9714	0.547	0.59	2.240
1956	9857	0.547	0.66	2.093
1957	4421	0.547	0.77	5.507
1958	8438	0.547	0.61	4.193
1959	12004	0.547	0.61	1.926
1960	7942	0.547	0.74	2.817
1961	14416	0.547	0.64	2.420
1962	15183	0.547	0.56	2.911
1963	7737	0.498	0.71	2.606
1964	10689	0.626	0.60	2.400
1965	22985	0.482	0.60	1.182
1966	13377	0.589	0.46	1.938
1967	12487	0.471	0.78	1.081
1968	13054	0.585	0.77	1.767
1969	6702	0.504	0.78	3.233
1970	10404	0.567	0.36	1.681
1971	9909	0.569	0.79	2.850
1972	5381	0.656	0.69	1.525
1973	11606	0.511	0.54	1.701
1974	13661	0.562	0.85	1.697
1975	4913	0.460	0.81	6.162
1976	4499	0.457	0.90	3.400
1977	10474	0.587	0.52	1.408
1978	11861	0.686	0.73	0.468
1979	2909	0.711	0.74	3.333
1980	5046	0.739	0.59	2.988
1981	2486	0.666	0.56	4.380
1982	2673	0.580	0.78	4.343
1983	3402	0.805	0.73	5.152
1984	3241	0.717	0.79	1.914
1985	2129	0.752	0.79	5.041
1986	3671	0.826	0.77	4.472
1987	2101	0.637	0.77	10.414
1988	3225	0.628	0.80	5.570
1989	5228	0.673	0.76	1.227
1990	5619	0.736	0.80	2.387
1991	4941	0.767	0.77	4.962
1992	1714	0.701	0.72	9.536
1993	2186	0.724	0.71	3.075
1994	4053	0.859	0.73	0.728
1995	2345	0.871	0.81	4.074
1996	2669	0.670	0.80	
1997	453	0.548	0.75	
1998	4291	0.601	0.80	

Table 4. For the upper Skeena aggregate, indices of escapement and total return derived from visual stream counts.

year	exploitation rate	records	p_{max}	escapement	*Z*-score	total return
1950	0.549	17	0.391	786	0.062	1742
1951	0.525	17	0.284	572	-0.290	1267
1952	0.525	16	0.449	905	0.369	2004
1953	0.525	22	0.402	810	0.134	1794
1954	0.525	18	0.422	849	0.203	1879
1955	0.525	22	0.474	955	0.383	2115
1956	0.525	19	0.504	1015	0.549	2249
1957	0.525	15	0.242	487	-0.441	1080
1958	0.525	24	0.484	974	0.588	2158
1959	0.525	23	0.463	932	0.396	2063
1960	0.525	25	0.383	771	0.095	1708
1961	0.525	19	0.403	810	0.232	1795
1962	0.525	23	0.521	1049	0.579	2323
1963	0.477	24	0.481	969	0.421	1937
1964	0.604	23	0.385	776	0.068	2084
1965	0.460	23	0.361	727	-0.011	1408
1966	0.567	22	0.281	566	-0.304	1383
1967	0.450	20	0.260	523	-0.335	992
1968	0.563	19	0.269	542	-0.268	1312
1969	0.482	26	0.308	620	-0.158	1254
1970	0.546	24	0.351	707	-0.031	1641
1971	0.548	14	0.365	735	0.013	1715
1972	0.634	12	0.480	966	0.397	2822
1973	0.489	11	0.404	814	0.155	1668
1974	0.540	8	0.351	706	0.053	1616
1975	0.439	9	0.106	214	-0.879	397
1976	0.435	9	0.154	310	-0.747	572
1977	0.565	9	0.413	832	0.284	2019
1978	0.665	9	0.509	1025	0.686	3276
1979	0.689	4	0.055	112	-0.938	387
1980	0.717	6	0.407	818	0.196	3149
1981	0.644	7	0.245	494	-0.497	1484
1982	0.558	5	0.274	551	-0.271	1314
1983	0.783	6	0.267	538	-0.101	2783
1984	0.695	8	0.206	414	-0.488	1472
1985	0.730	4	0.275	554	-0.305	2249
1986	0.804	6	0.260	523	-0.154	3038
1987	0.615	6	0.128	257	-0.734	713
1988	0.606	5	0.073	148	-0.965	398
1989	0.651	6	0.099	200	-0.728	613
1990	0.715	7	0.139	280	-0.558	1069
1991	0.745	6	0.152	305	-0.794	1319
1992	0.679	7	0.087	176	-0.820	592
1993	0.703	7	0.095	192	-0.832	696
1994	0.835	5	0.277	557	-0.366	1795
1995	0.851	3	0.066	132	-0.990	313
1996	0.634	1	0.125	252	-0.553	770
1997	0.524	2	0.028	56	-1.179	101
1998	0.597	6	0.388	782	0.358	1836

Table 5. For the lower and middle Skeena aggregate, indices of escapement and total return derived from visual stream counts.

year	exploitation rate	records	p_{max}	escapement	*Z*-score	total return
1950	0.549	29	0.191	793	-0.310	1757
1951	0.525	29	0.243	1011	-0.033	2239
1952	0.525	21	0.256	1066	0.068	2361
1953	0.525	24	0.179	743	-0.203	1646
1954	0.525	22	0.230	957	0.021	2120
1955	0.525	24	0.243	1013	0.078	2244
1956	0.525	23	0.253	1054	0.183	2334
1957	0.525	23	0.299	1246	0.411	2759
1958	0.525	25	0.468	1947	1.062	4312
1959	0.525	6	0.264	1099	0.010	2434
1960	0.525	11	0.246	1023	0.219	2266
1961	0.525	25	0.223	927	-0.102	2053
1962	0.525	23	0.196	816	-0.237	1807
1963	0.477	11	0.183	763	-0.122	1525
1964	0.604	32	0.395	1646	0.638	4422
1965	0.460	40	0.509	2120	1.071	4103
1966	0.567	53	0.436	1813	0.751	4430
1967	0.450	44	0.176	732	-0.262	1388
1968	0.563	52	0.632	2632	1.549	6366
1969	0.482	56	0.257	1071	0.008	2165
1970	0.546	54	0.304	1265	0.131	2936
1971	0.548	55	0.320	1332	0.201	3106
1972	0.634	55	0.297	1236	0.106	3610
1973	0.489	52	0.205	855	-0.232	1752
1974	0.540	52	0.212	882	-0.201	2018
1975	0.439	50	0.174	724	-0.361	1345
1976	0.435	50	0.216	901	-0.187	1662
1977	0.565	50	0.184	764	-0.331	1856
1978	0.665	52	0.233	971	-0.132	3106
1979	0.689	45	0.142	591	-0.515	2052
1980	0.717	53	0.196	817	-0.272	3145
1981	0.644	52	0.151	630	-0.475	1894
1982	0.558	47	0.187	780	-0.347	1861
1983	0.783	52	0.179	746	-0.335	3861
1984	0.695	54	0.277	1154	0.019	4105
1985	0.730	35	0.151	630	-0.416	2559
1986	0.804	49	0.411	1710	0.565	9939
1987	0.615	34	0.276	1149	0.109	3183
1988	0.606	27	0.067	279	-0.725	754
1989	0.651	39	0.222	924	-0.198	2834
1990	0.715	48	0.326	1358	0.274	5189
1991	0.745	41	0.233	970	-0.114	4190
1992	0.679	46	0.196	815	-0.245	2744
1993	0.703	34	0.115	479	-0.542	1737
1994	0.835	25	0.258	1073	0.129	3460
1995	0.851	18	0.207	859	-0.284	2034
1996	0.634	14	0.132	549	-0.510	1680
1997	0.524	14	0.060	251	-0.740	450
1998	0.597	29	0.264	1100	0.025	2582

Table 6. For the Area 3 aggregate, indices of escapement and total return derived from visual stream counts.

year	exploitation rate	records	p_{max}	escapement	*Z*-score	total return
1950	0.525	7	0.094	446	-0.68	940
1951	0.525	7	0.172	814	-0.35	1715
1952	0.525	8	0.104	492	-0.60	1037
1953	0.525	8	0.089	420	-0.66	885
1954	0.525	7	0.129	610	-0.53	1284
1955	0.525	7	0.270	1277	0.07	2690
1956	0.525	7	0.136	645	-0.48	1358
1957	0.525	7	0.129	609	-0.51	1282
1958	0.525	6	0.255	1207	-0.02	2542
1959	0.525	5	0.181	858	-0.31	1807
1960	0.525	1	0.200	947	-0.38	1993
1961	0.525	3	0.389	1840	0.35	3876
1962	0.525	3	0.233	1104	-0.31	2325
1963	0.477	6	0.489	2313	0.75	4419
1964	0.604	8	0.438	2072	0.70	5233
1965	0.460	13	0.649	3070	1.35	5688
1966	0.567	13	0.585	2769	1.09	6397
1967	0.450	9	0.398	1882	0.37	3419
1968	0.563	13	0.544	2573	0.82	5889
1969	0.482	11	0.259	1227	-0.09	2370
1970	0.546	14	0.388	1834	0.35	4038
1971	0.548	15	0.457	2163	0.54	4784
1972	0.634	10	0.257	1218	-0.14	3328
1973	0.489	7	0.223	1053	-0.24	2062
1974	0.540	7	0.193	915	-0.45	1990
1975	0.439	9	0.218	1032	-0.24	1839
1976	0.435	17	0.233	1102	-0.31	1952
1977	0.565	17	0.247	1171	-0.27	2692
1978	0.665	19	0.265	1255	-0.15	3743
1979	0.689	19	0.130	613	-0.68	1971
1980	0.717	19	0.148	702	-0.60	2480
1981	0.644	19	0.244	1156	-0.21	3248
1982	0.558	20	0.207	977	-0.35	2210
1983	0.783	19	0.280	1324	-0.07	6101
1984	0.695	20	0.390	1845	0.42	6048
1985	0.730	17	0.478	2263	0.71	8383
1986	0.804	17	0.333	1574	0.11	8034
1987	0.615	14	0.335	1585	0.11	4122
1988	0.606	12	0.180	850	-0.51	2159
1989	0.651	17	0.286	1354	-0.14	3882
1990	0.715	18	0.413	1953	0.34	6848
1991	0.745	13	0.239	1131	-0.27	4434
1992	0.679	9	0.347	1642	0.24	5123
1993	0.703	7	0.244	1156	-0.29	3887
1994	0.835	3	0.592	2802	1.18	16952
1995	0.851	5	0.294	1389	0.09	9348
1996	0.634	5	0.306	1450	0.16	3959
1997	0.524	4	0.126	594	-0.71	1249
1998	0.597	3	0.241	1140	-0.16	2830

Table 7. For the Area 5 (Principe/Grenville) aggregate, indices of escapement and total return derived from visual stream counts.

year	exploitation rate	records	p_{max}	escapement	*Z*-score	total return
1950	0.549	26	0.254	821	-0.19	1819
1951	0.549	26	0.303	978	-0.01	2166
1952	0.549	32	0.346	1117	0.12	2475
1953	0.549	31	0.331	1069	0.12	2367
1954	0.549	33	0.359	1160	0.25	2568
1955	0.549	33	0.443	1431	0.54	3169
1956	0.549	33	0.472	1526	0.59	3379
1957	0.549	27	0.450	1453	0.52	3217
1958	0.549	37	0.307	993	0.01	2199
1959	0.549	28	0.421	1360	0.57	3013
1960	0.549	32	0.335	1083	0.20	2399
1961	0.549	38	0.544	1756	0.85	3890
1962	0.549	27	0.324	1047	0.12	2320
1963	0.500	32	0.454	1466	0.55	2930
1964	0.628	35	0.568	1835	1.11	4932
1965	0.483	33	0.669	2160	1.54	4181
1966	0.591	41	0.574	1855	1.00	4535
1967	0.473	38	0.304	982	0.01	1862
1968	0.587	38	0.486	1569	0.75	3794
1969	0.505	37	0.157	507	-0.45	1026
1970	0.569	33	0.076	246	-0.73	571
1971	0.571	31	0.097	314	-0.68	731
1972	0.658	35	0.141	455	-0.48	1329
1973	0.512	31	0.163	527	-0.35	1080
1974	0.563	24	0.217	700	-0.24	1603
1975	0.461	24	0.307	991	0.08	1841
1976	0.458	15	0.186	602	-0.30	1110
1977	0.588	17	0.244	790	-0.09	1917
1978	0.687	21	0.232	748	-0.20	2393
1979	0.712	31	0.139	449	-0.51	1558
1980	0.740	30	0.113	365	-0.59	1405
1981	0.667	27	0.207	669	-0.27	2012
1982	0.581	9	0.041	134	-0.83	319
1983	0.807	23	0.088	283	-0.73	1464
1984	0.719	35	0.094	304	-0.69	1081
1985	0.754	15	0.120	387	-0.56	1570
1986	0.828	42	0.224	725	-0.31	4214
1987	0.639	14	0.154	496	-0.48	1375
1988	0.630	16	0.206	665	-0.35	1797
1989	0.674	1	0.067	215	-0.67	661
1990	0.738	26	0.073	236	-0.76	902
1991	0.769	24	0.047	150	-0.85	649
1992	0.703	26	0.063	204	-0.79	687
1993	0.724	11	0.058	186	-0.76	675
1994	0.690	2	0.187	603	-0.18	1944
1995	0.577	0	0.138	445	-0.05	1053
1996	0.673	0	0.126	408	-0.04	1248
1997	0.443	1	0.333	1077	0.48	1933
1998	0.574	4	0.205	662	-0.38	1555

Table 8. For the Area 6 aggregate, indices of escapement and total return derived from visual stream counts.

year	exploitation rate	records	p_{max}	escapement	*Z*-score	total return
1950	0.527	80	0.223	1022	-0.071	2159
1951	0.527	84	0.458	2102	1.164	4442
1952	0.527	9	0.362	1662	0.108	3513
1953	0.527	83	0.298	1366	0.364	2887
1954	0.527	82	0.353	1621	0.581	3426
1955	0.527	84	0.267	1224	0.205	2587
1956	0.527	84	0.458	2102	1.121	4442
1957	0.527	61	0.428	1964	1.158	4150
1958	0.527	65	0.222	1020	0.045	2155
1959	0.527	74	0.185	851	-0.179	1798
1960	0.527	66	0.214	984	-0.002	2080
1961	0.527	71	0.217	996	0.014	2104
1962	0.527	74	0.319	1462	0.531	3090
1963	0.478	73	0.387	1778	1.113	3406
1964	0.606	70	0.270	1238	0.696	3142
1965	0.462	55	0.445	2044	1.339	3796
1966	0.569	34	0.244	1120	0.011	2599
1967	0.451	57	0.196	900	-0.139	1639
1968	0.565	58	0.362	1659	0.865	3813
1969	0.484	42	0.136	625	-0.327	1209
1970	0.547	50	0.155	711	-0.241	1570
1971	0.550	49	0.194	890	-0.056	1976
1972	0.636	55	0.232	1064	0.082	2923
1973	0.490	46	0.129	594	-0.350	1166
1974	0.541	49	0.148	680	-0.320	1481
1975	0.440	41	0.196	898	-0.082	1602
1976	0.436	50	0.166	764	-0.217	1355
1977	0.566	55	0.127	583	-0.411	1345
1978	0.666	53	0.128	588	-0.398	1758
1979	0.690	58	0.159	730	-0.273	2357
1980	0.718	52	0.104	476	-0.532	1691
1981	0.646	58	0.113	520	-0.459	1468
1982	0.559	67	0.131	602	-0.403	1365
1983	0.785	56	0.086	395	-0.591	1838
1984	0.697	66	0.122	559	-0.415	1846
1985	0.732	81	0.130	597	-0.410	2227
1986	0.806	78	0.149	685	-0.339	3532
1987	0.617	75	0.100	461	-0.539	1204
1988	0.608	48	0.070	321	-0.645	819
1989	0.652	45	0.083	383	-0.582	1102
1990	0.716	30	0.121	555	-0.457	1958
1991	0.747	47	0.082	376	-0.573	1484
1992	0.681	43	0.087	401	-0.514	1258
1993	0.703	36	0.075	344	-0.603	1157
1994	0.665	36	0.065	298	-0.603	888
1995	0.558	32	0.032	146	-0.825	330
1996	0.636	30	0.087	397	-0.559	1093
1997	0.419	37	0.028	131	-0.850	225
1998	0.570	53	0.122	561	-0.372	1305

Table 9. For the Area 7 (Bella Bella) aggregate, indices of escapement and total return derived from visual stream counts.

year	exploitation rate	records	p_{max}	escapement	*Z*-score	total return
1950	0.527	20	0.251	412	0.007	870
1951	0.527	21	0.373	613	0.420	1295
1952	0.527	29	0.491	806	0.693	1703
1953	0.527	32	0.429	706	0.512	1491
1954	0.527	30	0.447	735	0.472	1552
1955	0.527	32	0.506	832	0.756	1758
1956	0.527	33	0.477	783	0.719	1656
1957	0.527	22	0.336	552	0.068	1166
1958	0.527	21	0.269	442	-0.099	934
1959	0.527	25	0.393	647	0.385	1366
1960	0.527	23	0.182	299	-0.371	632
1961	0.527	30	0.411	676	0.574	1428
1962	0.527	28	0.413	679	0.420	1434
1963	0.478	28	0.279	458	0.052	877
1964	0.606	27	0.439	722	0.549	1832
1965	0.462	26	0.537	882	1.065	1638
1966	0.569	28	0.411	676	0.644	1569
1967	0.451	27	0.256	421	-0.067	767
1968	0.565	27	0.390	641	0.454	1473
1969	0.484	30	0.226	371	-0.172	718
1970	0.547	24	0.214	351	-0.202	776
1971	0.550	26	0.324	532	0.212	1182
1972	0.636	26	0.219	359	-0.148	987
1973	0.490	21	0.149	244	-0.458	479
1974	0.541	23	0.261	429	-0.049	936
1975	0.440	12	0.195	320	-0.178	570
1976	0.436	20	0.247	406	-0.148	719
1977	0.566	20	0.146	239	-0.424	552
1978	0.666	16	0.173	285	-0.319	852
1979	0.690	19	0.123	202	-0.493	653
1980	0.718	10	0.042	69	-0.794	244
1981	0.646	9	0.193	318	-0.146	896
1982	0.559	15	0.105	172	-0.629	389
1983	0.785	10	0.078	128	-0.752	597
1984	0.697	17	0.072	118	-0.702	390
1985	0.732	21	0.057	93	-0.756	348
1986	0.806	20	0.064	104	-0.724	539
1987	0.617	17	0.075	123	-0.708	321
1988	0.608	18	0.045	74	-0.825	188
1989	0.652	23	0.040	66	-0.843	188
1990	0.716	18	0.094	154	-0.621	542
1991	0.747	17	0.057	93	-0.780	367
1992	0.681	16	0.080	131	-0.701	411
1993	0.703	17	0.071	117	-0.735	394
1994	0.665	1	0.188	308	-0.307	920
1995	0.558	0	0.101	166	-0.049	375
1996	0.636	0	0.169	277	-0.083	763
1997	0.419	3	0.097	159	-0.552	274
1998	0.570	13	0.308	506	0.197	1176

Table 10. For the Area 8 (Bella Coola) aggregate, indices of escapement and total return derived from visual stream counts.

year	exploitation rate	records	p_{max}	escapement	*Z*-score	total return
1950	0.527	19	0.453	3048	0.187	6441
1951	0.527	20	0.588	3957	0.620	8363
1952	0.527	22	0.349	2348	-0.077	4962
1953	0.527	20	0.374	2520	-0.033	5326
1954	0.527	22	0.536	3611	0.456	7631
1955	0.527	22	0.493	3317	0.393	7009
1956	0.527	21	0.596	4013	0.561	8480
1957	0.527	23	0.460	3099	0.187	6549
1958	0.527	21	0.451	3034	0.182	6412
1959	0.527	12	0.749	5041	1.131	10653
1960	0.527	11	0.362	2439	-0.076	5154
1961	0.527	15	0.680	4579	0.897	9676
1962	0.527	8	0.365	2461	-0.060	5200
1963	0.478	11	0.467	3147	0.157	6028
1964	0.606	9	0.437	2941	0.043	7466
1965	0.462	8	0.632	4256	0.706	7905
1966	0.569	12	0.474	3193	0.428	7410
1967	0.451	5	0.146	983	-0.676	1790
1968	0.565	14	0.607	4088	0.737	9394
1969	0.484	6	0.233	1568	-0.435	3037
1970	0.547	10	0.576	3880	0.659	8573
1971	0.550	14	0.364	2448	-0.040	5435
1972	0.636	11	0.327	2201	-0.204	6046
1973	0.490	16	0.343	2313	-0.190	4536
1974	0.541	15	0.312	2097	-0.287	4572
1975	0.440	17	0.287	1932	-0.286	3447
1976	0.436	21	0.406	2732	0.093	4847
1977	0.566	18	0.221	1489	-0.408	3433
1978	0.666	15	0.203	1365	-0.501	4082
1979	0.690	15	0.357	2405	-0.114	7763
1980	0.718	12	0.129	869	-0.668	3086
1981	0.646	13	0.146	985	-0.623	2779
1982	0.559	15	0.119	801	-0.698	1817
1983	0.785	17	0.165	1108	-0.589	5156
1984	0.697	15	0.277	1866	-0.299	6160
1985	0.732	12	0.103	693	-0.717	2588
1986	0.806	8	0.095	637	-0.746	3288
1987	0.617	5	0.113	758	-0.707	1980
1988	0.608	3	0.226	1524	-0.382	3887
1989	0.652	4	0.152	1020	-0.491	2934
1990	0.716	3	0.568	3827	0.750	13497
1991	0.747	10	0.276	1856	-0.113	7331
1992	0.681	6	0.129	870	-0.576	2730
1993	0.703	6	0.108	728	-0.652	2449
1994	0.665	2	0.383	2581	0.317	7704
1995	0.558	1	0.200	1347	-0.424	3048
1996	0.636	2	0.301	2028	-0.131	5579
1997	0.419	1	0.400	2693	0.152	4635
1998	0.570	9	0.212	1424	-0.403	3312

Table 11. For the Central Coast aggregate (Areas 9 and 10), indices of escapement derived from visual stream counts.

year	records	p_{max}	escapement	*Z*-score
1950	14	0.387	922	0.380
1951	17	0.375	894	0.250
1952	15	0.739	1763	1.602
1953	15	0.231	551	-0.244
1954	8	0.280	668	0.164
1955	7	0.339	809	-0.056
1956	5	0.142	339	-0.512
1957	7	0.120	287	-0.544
1958	13	0.293	699	0.232
1959	10	0.243	579	-0.104
1960	10	0.111	264	-0.679
1961	14	0.455	1086	0.900
1962	15	0.569	1359	1.098
1963	18	0.295	704	0.173
1964	15	0.431	1028	0.687
1965	10	0.449	1070	0.568
1966	12	0.150	359	-0.448
1967	10	0.050	119	-0.831
1968	11	0.195	464	-0.293
1969	19	0.200	477	-0.208
1970	16	0.159	379	-0.418
1971	11	0.222	530	-0.154
1972	10	0.353	842	0.362
1973	18	0.203	485	-0.317
1974	18	0.403	961	0.564
1975	7	0.178	425	-0.412
1976	11	0.151	360	-0.442
1977	13	0.173	413	-0.431
1978	15	0.206	492	-0.249
1979	13	0.244	582	-0.042
1980	10	0.252	602	-0.027
1981	17	0.227	541	-0.244
1982	17	0.261	623	-0.091
1983	17	0.293	699	0.026
1984	17	0.394	941	0.538
1985	15	0.152	363	-0.521
1986	10	0.114	273	-0.529
1987	8	0.144	343	-0.424
1988	8	0.084	201	-0.596
1989	10	0.042	100	-0.841
1990	3	0.058	139	-0.762
1991	0	–	–	–
1992	0	–	–	–
1993	2	0.185	440	-0.336
1994	0	–	–	–
1995	0	–	–	–
1996	0	–	–	–
1997	0	–	–	–
1998	0	–	–	–

Table 12. Escapement indices for the three Statistical Areas on the Queen Charlotte Islands. The p_{max} values can be converted to average-stream escapements with the following average maximum escapements: Area 1, 14,433; Area 2W, 5376; and Area 2E, 3407.

	Area 1 – QCI north		Area 2W – QCI west		Area 2E – QCI east	
year	records	p_{max}	records	p_{max}	records	p_{max}
1950	8	0.350	40	0.159	32	0.112
1951	9	0.318	40	0.287	31	0.278
1952	7	0.190	50	0.375	43	0.405
1953	4	0.187	39	0.183	35	0.183
1954	7	0.352	39	0.262	32	0.242
1955	5	0.204	26	0.162	21	0.152
1956	6	0.121	30	0.186	24	0.202
1957	8	0.241	35	0.246	27	0.247
1958	7	0.146	33	0.237	26	0.261
1959	10	0.326	37	0.320	27	0.317
1960	13	0.127	43	0.231	30	0.276
1961	12	0.326	37	0.355	25	0.369
1962	11	0.429	42	0.383	31	0.367
1963	10	0.114	36	0.286	26	0.353
1964	13	0.458	48	0.444	35	0.439
1965	13	0.574	38	0.361	25	0.250
1966	10	0.151	50	0.501	40	0.588
1967	13	0.174	57	0.315	44	0.357
1968	11	0.135	53	0.217	42	0.239
1969	8	0.072	53	0.441	45	0.507
1970	13	0.266	40	0.432	27	0.511
1971	15	0.072	28	0.130	13	0.198
1972	15	0.235	31	0.283	16	0.328
1973	15	0.245	35	0.311	20	0.360
1974	15	0.517	31	0.309	16	0.115
1975	15	0.376	62	0.377	47	0.377
1976	15	0.656	57	0.405	42	0.316
1977	15	0.338	60	0.285	45	0.267
1978	15	0.436	57	0.310	42	0.265
1979	15	0.324	54	0.219	39	0.178
1980	13	0.126	49	0.135	36	0.138
1981	15	0.171	62	0.152	47	0.145
1982	15	0.290	65	0.148	50	0.106
1983	14	0.242	70	0.153	56	0.131
1984	15	0.274	60	0.159	45	0.121
1985	15	0.221	51	0.150	36	0.121
1986	15	0.285	67	0.196	52	0.170
1987	15	0.293	75	0.171	60	0.140
1988	15	0.179	71	0.174	56	0.173
1989	11	0.137	69	0.146	58	0.148
1990	6	0.139	60	0.122	54	0.121
1991	7	0.151	63	0.127	56	0.124
1992	6	0.128	57	0.111	51	0.109
1993	2	0.411	58	0.117	56	0.107
1994	0	–	33	0.056	33	0.056
1995	0	–	37	0.108	37	0.108

year	Area 1 – QCI north records	Area 1 – QCI north p_{max}	Area 2W – QCI west records	Area 2W – QCI west p_{max}	Area 2E – QCI east records	Area 2E – QCI east p_{max}
1996	0	–	37	0.087	37	0.087
1997	0	–	34	0.099	34	0.099
1998	12	0.247	58	0.210	46	0.200

Table 13. Summary of the Ricker stock-recruitment analyses on reconstructed time series for six northern BC coho aggregates.

aggregate	Ricker stock-recruitment analysis N	adj. r^2	a'	b'	S_{MSY}	u_{MSY}
Babine Lake aggregate	49	0.382	1.730	20667	7831	0.66
upper Skeena	44	0.283	1.631	1643	252	0.63
lower and middle Skeena	45	0.358	1.978	2251	814	0.72
Nass (Area 3)	46	0.305	1.834	3613	1343	0.68
Principe (Area 5)	46	0.41	1.874	2121	782	0.69
Kitimat (Area 6)	46	0.350	1.394	397	1244	0.56
Bella Bella (Area 7)	46	0.434	1.505	1107	437	0.59
Bella Coola (Area 8)	46	0.241	1.855	5171	1914	0.69

Table 14. Summary of abundance forecasts for six nBC coho aggregates. Details of these forecasts are contained in Table 15 to Table 22. Abundance forecasts are in units of average-stream escapement and are not total coho returns to the aggregate.

aggregate	reconstructed abundance		A_{1998}	$\hat{A}_{1999}$ forecast abundance			
	average	standard deviation	1998 abundance	stock-recruitment	Z-score†	3YRA time series model	Z-score†
Babine Lake	19,481	9,625	10,763	10,774	-0.90	4,436	-1.56
upper Skeena	1,559	768	1,836	948	-0.79	522	-1.35
lower & middle Skeena	2,783	1,554	2,582	2,364	-0.27	1,249	-0.99
Area 3	3,813	2,805	2,830	3,442	-0.13	2,410	-0.50
Area 5	2,019	1,130	1,555	1,572	-0.40	1,554	-0.41
Area 6	2,097	1,051	1,305	1,244	-0.81	685	-1.34
Area 7	881	482	1,176	942	0.13	627	-0.53
Area 8	5,542	2,543	3,312	4,840	-0.28	4,408	-0.45

†Z-score = (observation – mean)/standard deviation). For time series with N between 45 and 49 about 50% of observations lie within a Z-score of ±0.68 while about 90% of observations lie within a Z-score of ±1.67.

Table 15. Confidence intervals around the forecast of total return and escapement for the Babine coho aggregate in 1999 derived from the stock-recruitment analysis. Confidence intervals around the escapement forecast are given for three exploitation rates. An exploitation rate of 0.4 is a reasonable estimate of the Alaskan exploitation rate. A total exploitation rate of 0.6 was observed in 1998 and the value of 0.704 was the observed average between 1976 and 1996. The 3YRA time-series model forecast of total return and its confidence interval are also given.

probability of a lower value	log *R*/*S*	total return	total return	escapement		
			3YRA	*u* = 0.4	*u* = 0.6	*u* = 0.704
99%	2.6076	31163	23372	18698	12465	9224
95%	2.2425	22303	14080	13382	8921	6602
90%	2.0498	18779	10842	11268	7512	5559
75%	1.7354	14306	7072	8584	5722	4235
50%	**1.3906**	**10774**	**4436**	**6465**	**4310**	**3189**
25%	1.0457	8273	2783	4964	3309	2449
10%	0.7314	6634	1815	3980	2653	1964
5%	0.5387	5856	1398	3514	2342	1733
1%	0.1736	4737	842	2842	1895	1402

Table 16. Confidence intervals around the forecast of total return and escapement for the upper Skeena coho aggregate in 1999 derived from the stock-recruitment analysis. An exploitation rate of 0.45 is the average of the observed values at the Skeena indicators in 1998. The escapement forecast is expressed as an "average stream" escapement and as a *Z*-score or standardized escapement. The time-series forecast of total return (model 3YRA) is also shown.

probability of a lower value	log *R*/*S*	total return	total return	escapement	standardized escapement
			3YRA	*u* = 0.45	*Z*-score
99%	2.325	1958	2793	1077	1.115
95%	2.013	1540	1675	847	0.765
90%	1.853	1367	1287	752	0.591
75%	1.586	1138	836	626	0.324
50%	**1.294**	**948**	**522**	**521**	**0.058**
25%	1.002	806	326	443	-0.179
10%	0.736	708	212	390	-0.367
5%	0.573	660	163	363	-0.470
1%	0.263	588	98	323	-0.640

Table 17. Confidence intervals around the forecast of total return and escapement for the lower and middle Skeena aggregate in 1999 derived from the stock-recruitment analysis. An exploitation rate of 0.45 is the average of the observed values at the Skeena indicators in 1998. The escapement forecast is expressed as an "average stream" escapement and as a *Z*-score or standardized escapement. The time-series forecast of total return (model 3YRA) is also shown.

probability of a lower value	log *R*/*S*	total return	total return 3YRA	escapement $u = 0.45$	standardized escapement *Z*-score
99%	2.468	4953	5330	2724	2.452
95%	2.148	3873	3424	2130	1.885
90%	1.980	3427	2726	1885	1.604
75%	1.705	2844	1877	1564	1.174
50%	**1.403**	**2364**	**1249**	**1300**	**0.748**
25%	1.101	2010	832	1105	0.374
10%	0.826	1767	573	972	0.078
5%	0.658	1649	456	907	-0.082
1%	0.338	1472	293	809	-0.344

Table 18. Confidence intervals around the forecast of total return and escapement for the Area 3 coho aggregate in 1999 derived from the stock-recruitment analysis. An exploitation rate of 0.46 was observed in 1998 at Lachmach, which is part of this aggregate. The escapement forecast is expressed as an "average stream" escapement and as a *Z*-score or standardized escapement. The time-series forecast of total return (model 3YRA) is also shown.

probability of a lower value	log *R*/*S*	total return	total return 3YRA	escapement $u = 0.54$	standardized escapement *Z*-score
99%	2.180	8923	9641	4818	2.800
95%	1.818	6548	6316	3536	2.174
90%	1.628	5601	5079	3025	1.857
75%	1.316	4396	3556	2374	1.367
50%	**0.975**	**3442**	**2410**	**1859**	**0.872**
25%	0.633	2764	1633	1492	0.427
10%	0.322	2318	1143	1252	0.071
5%	0.131	2106	919	1137	-0.123
1%	-0.231	1800	602	972	-0.441

Table 19. Confidence intervals around the forecast of total return and escapement for the Area 5 coho aggregate in 1999 derived from the stock-recruitment analysis. An exploitation rate of 0.30 was observed in 1998 at Toboggan Creek. The escapement forecast is expressed as an "average stream" escapement and as a *Z*-score or standardized escapement. The time-series forecast of total return (model 3YRA) is also shown.

probability of a lower value	log *R*/*S*	total return	total return	escapement	standardized escapement
			3YRA	*u* = 0.30	*Z*-score
99%	2.716	4365	6016	3055	2.135
95%	2.309	3107	3981	2175	1.664
90%	2.094	2623	3218	1836	1.429
75%	1.743	2026	2272	1418	1.071
50%	1.359	1572	1554	1100	0.719
25%	0.974	1262	1063	884	0.416
10%	0.624	1068	750	747	0.183
5%	0.409	978	606	684	0.062
1%	0.002	852	401	597	-0.129

Table 20. Confidence intervals around the forecast of total return and escapement for the Area 6 coho aggregate in 1999 derived from the stock-recruitment analysis. An exploitation rate of 0.30 was observed in 1998 at Toboggan Creek. The escapement forecast is expressed as an "average stream" escapement and as a *Z*-score or standardized escapement. The time-series forecast of total return (model 3YRA) is also shown.

probability of a lower value	log *R*/*S*	total return	total return	escapement	standardized escapement
			3YRA	*u* = 0.30	*Z*-score
99%	2.033	2357	2050	1650	1.254
95%	1.757	1911	1467	1338	0.928
90%	1.612	1721	1235	1205	0.765
75%	1.374	1464	932	1025	0.514
50%	**1.114**	**1244**	**685**	**871**	**0.262**
25%	0.854	1075	503	753	0.034
10%	0.616	955	380	668	-0.150
5%	0.471	894	320	626	-0.252
1%	0.195	801	229	560	-0.424

Table 21. Confidence intervals around the forecast of total return and escapement for the Area 7 (Bella Bella) aggregate in 1999 derived from the stock-recruitment analysis. The escapement forecast is expressed as an "average stream" escapement and as a *Z*-score or standardized escapement. The time-series forecast of total return (model 3YRA) is also shown.

probability of a lower value	log *R*/*S*	total return	total return	escapement	standardized escapement
			3YRA	*u* = 0.30	*Z*-score
99%	1.977	1676	1799	1173	1.781
95%	1.701	1382	1304	967	1.528
90%	1.555	1256	1105	879	1.403
75%	1.317	1087	842	761	1.213
50%	**1.056**	**942**	**627**	**659**	**1.025**
25%	0.795	830	466	581	0.860
10%	0.557	751	355	526	0.729
5%	0.411	711	301	498	0.657
1%	0.135	649	218	455	0.538

Table 22. Confidence intervals around the forecast of total return and escapement for the Area 8 (Bella Coola) aggregate in 1999 derived from the stock-recruitment analysis. The escapement forecast is expressed as an "average stream" escapement and as a *Z*-score or standardized escapement. The time-series forecast of total return (model 3YRA) is also shown.

probability of a lower value	log *R*/*S*	total return	total return	escapement	standardized escapement
			3YRA	*u* = 0.30	*Z*-score
99%	2.004	10462	16643	7323	2.252
95%	1.719	8189	11098	5733	1.825
90%	1.569	7227	9006	5059	1.606
75%	1.324	5935	6400	4155	1.263
50%	**1.055**	**4840**	**4408**	**3388**	**0.906**
25%	0.787	4002	3036	2801	0.574
10%	0.542	3412	2158	2388	0.296
5%	0.392	3115	1751	2181	0.137
1%	0.107	2662	1168	1863	-0.138

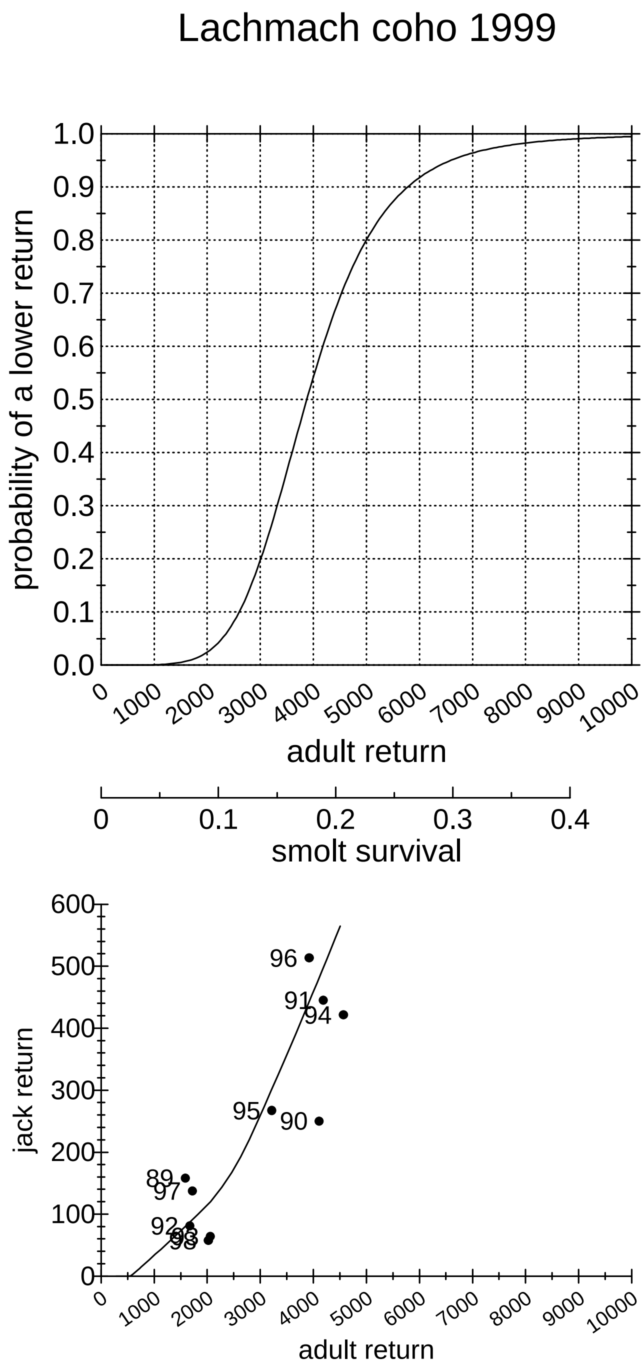

Figure 1. Return and survival forecast for Lachmach River coho in 1999 using the sibling regression model. The lower panel is the sibling relationship. The upper panel is the probability distribution for the predicted age 3+4 return. Returns can be converted to survival using the middle scale.

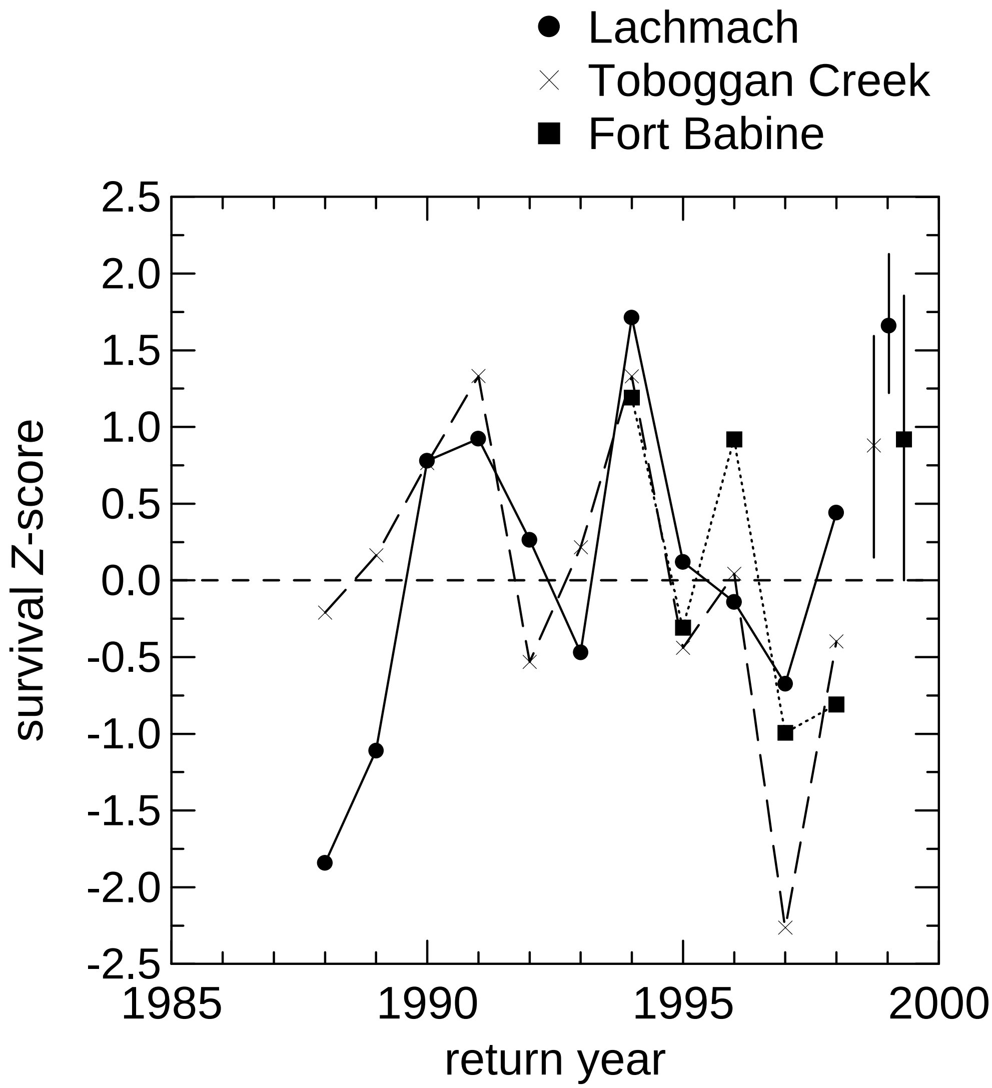

Figure 2. Time series of standardized survivals for three northern BC coho indicators. Forecast survivals for 1999 are shown with 50% confidence intervals.

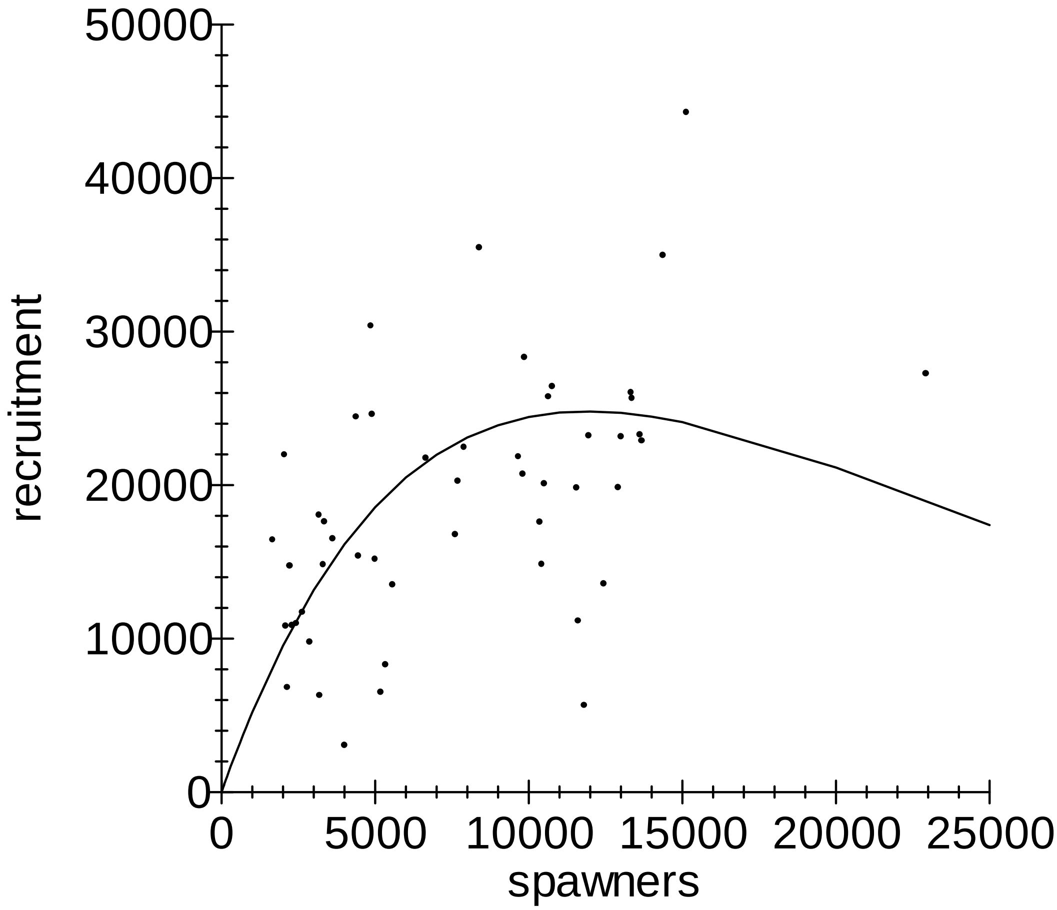

Figure 3. Ricker stock-recruitment function for the Babine Lake coho aggregate to brood year 1995.

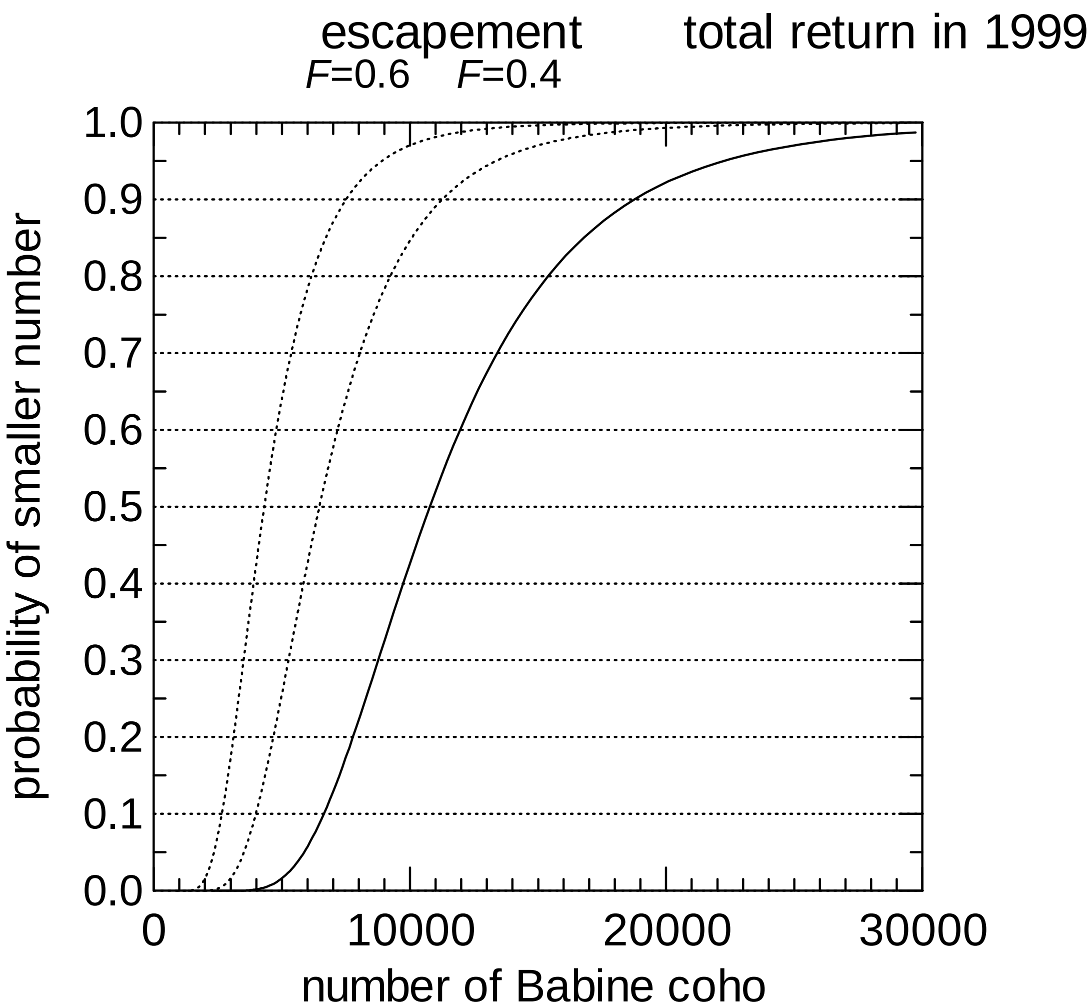

Figure 4. Stock-recruitment forecast for Babine coho aggregate in 1999. Escapement (dotted lines) is forecast for two exploitation rates (0.4 and 0.6). The solid line is the forecast for the total return in 1999.

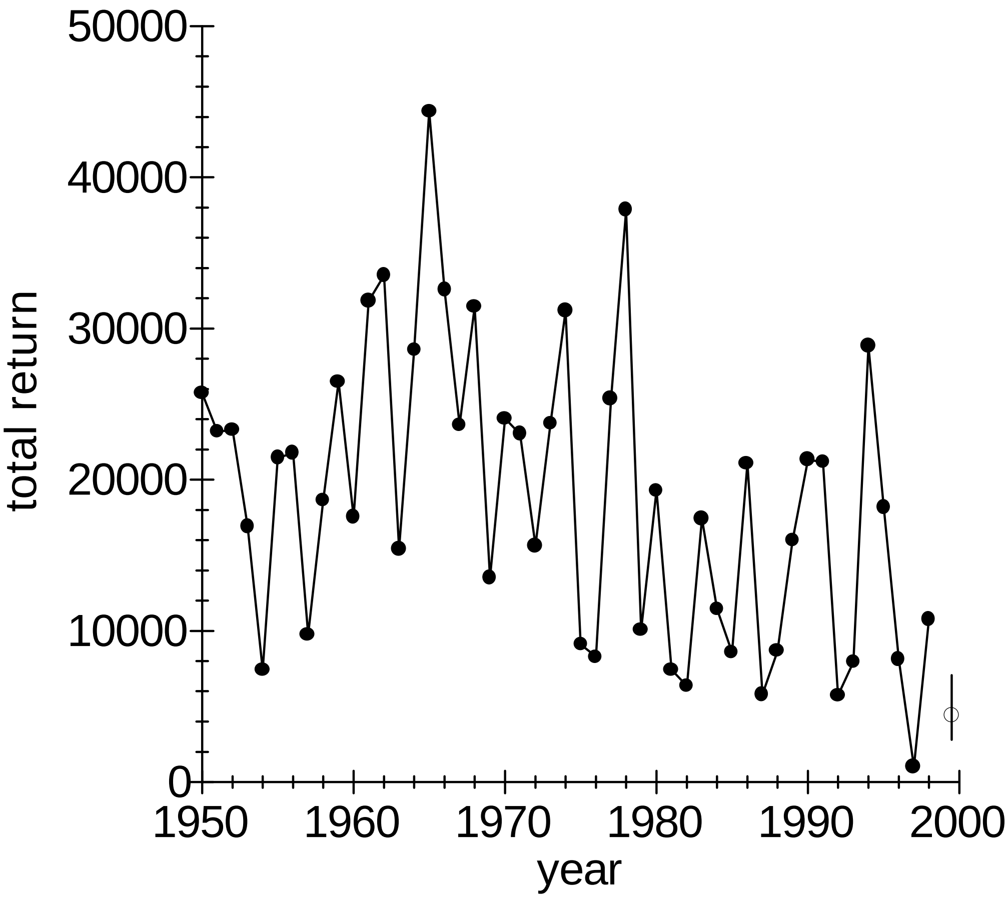

Figure 5. Estimated total return of the Babine Lake coho aggregate. The 3YRA time-series forecast with 50% CI is shown.

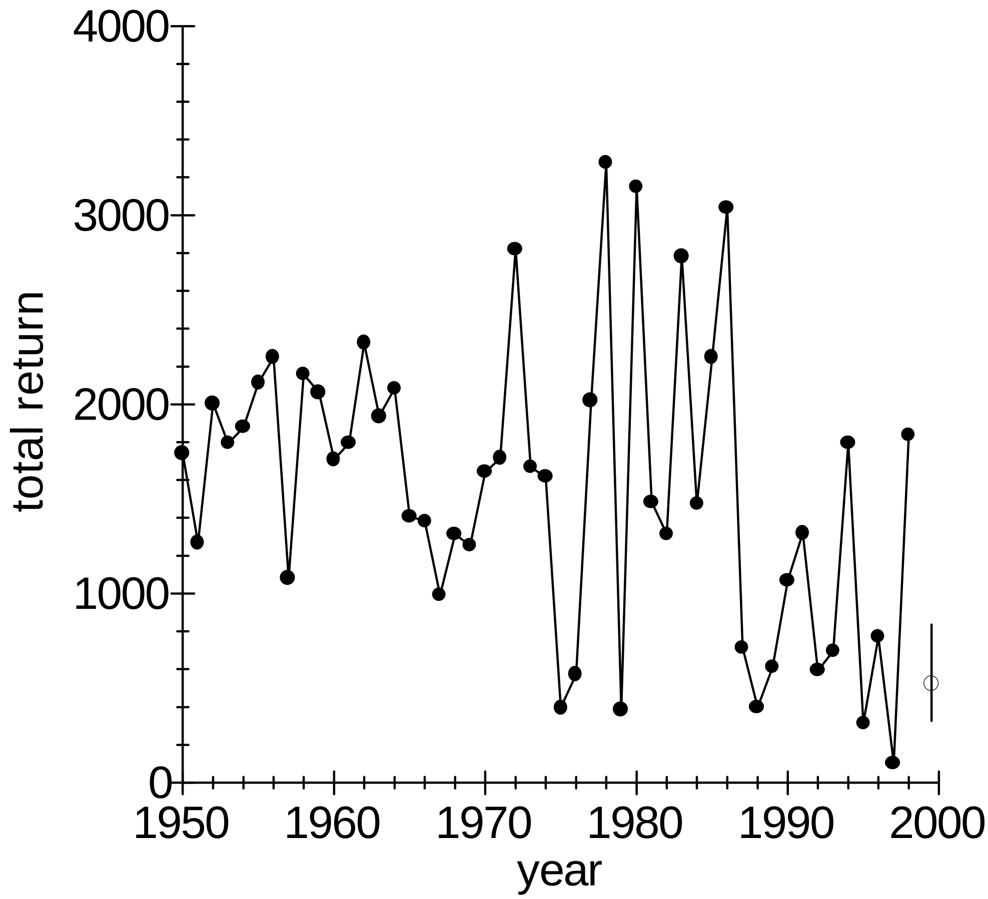

Figure 6. Total return for the average stream in the upper Skeena (Area 4). The 3YRA forecast and 50% CI are shown.

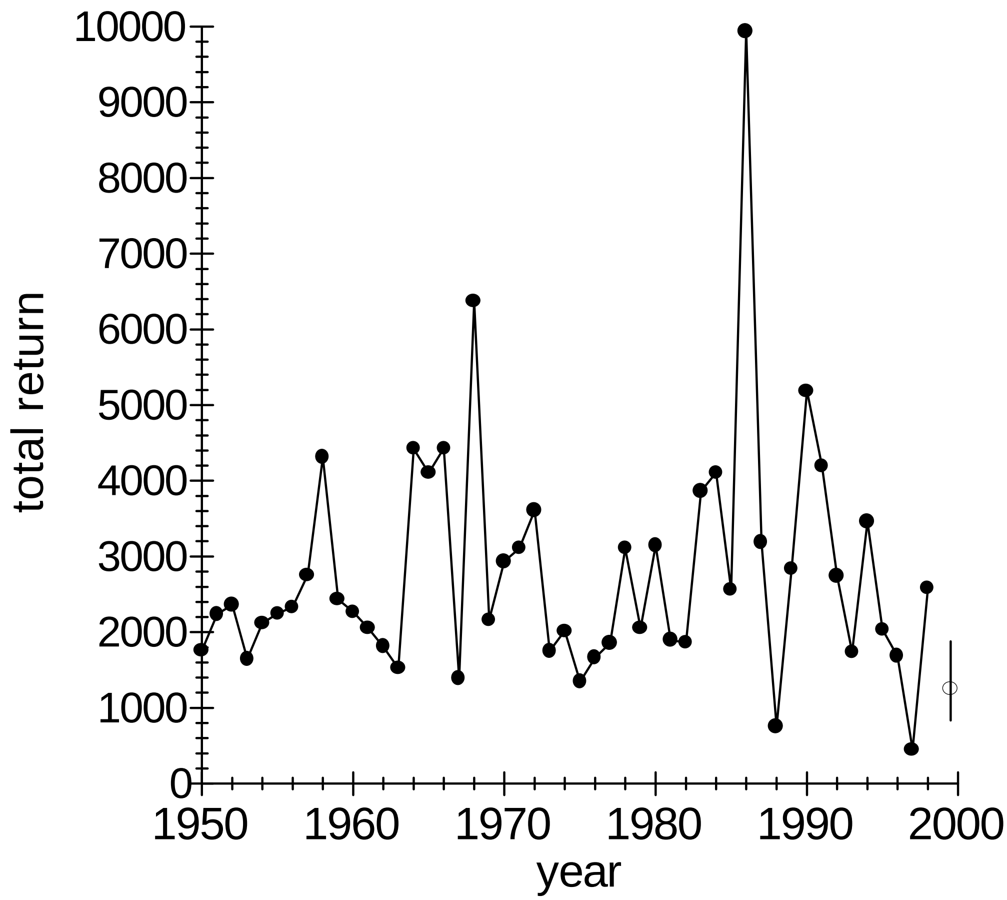

Figure 7. Total return for the average stream in the lower and middle Skeena (Area 4). The 3YRA forecast and 50% CI are shown.

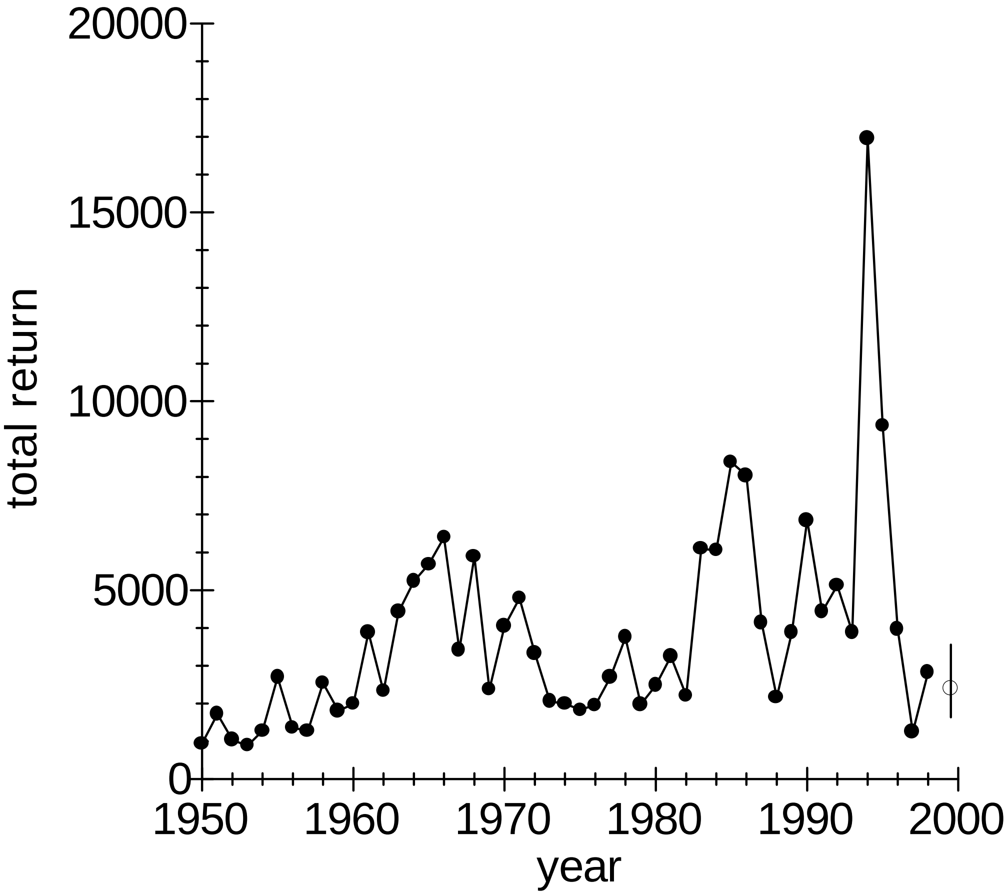

Figure 8. Total return to the average stream in Area 3. The 3YRA forecast and 50% CI are shown.

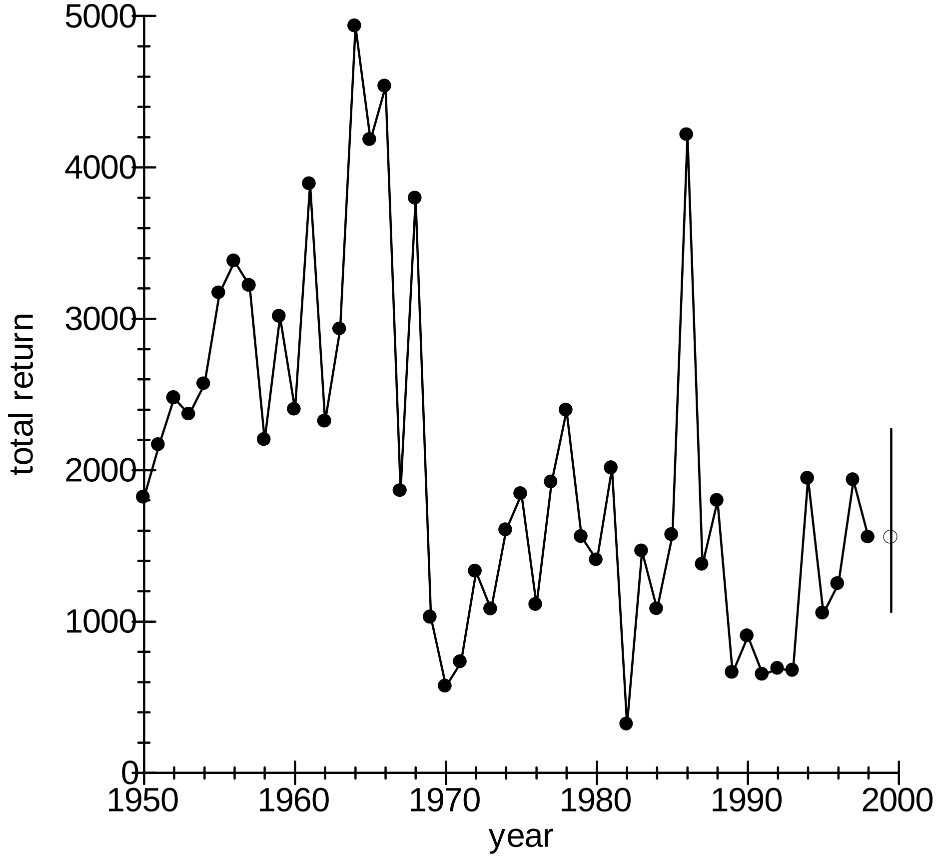

Figure 9. Total return to the average stream of the Principe/Grenville (Area 5) aggregate. The 3YRA forecast and 50% CI are shown.

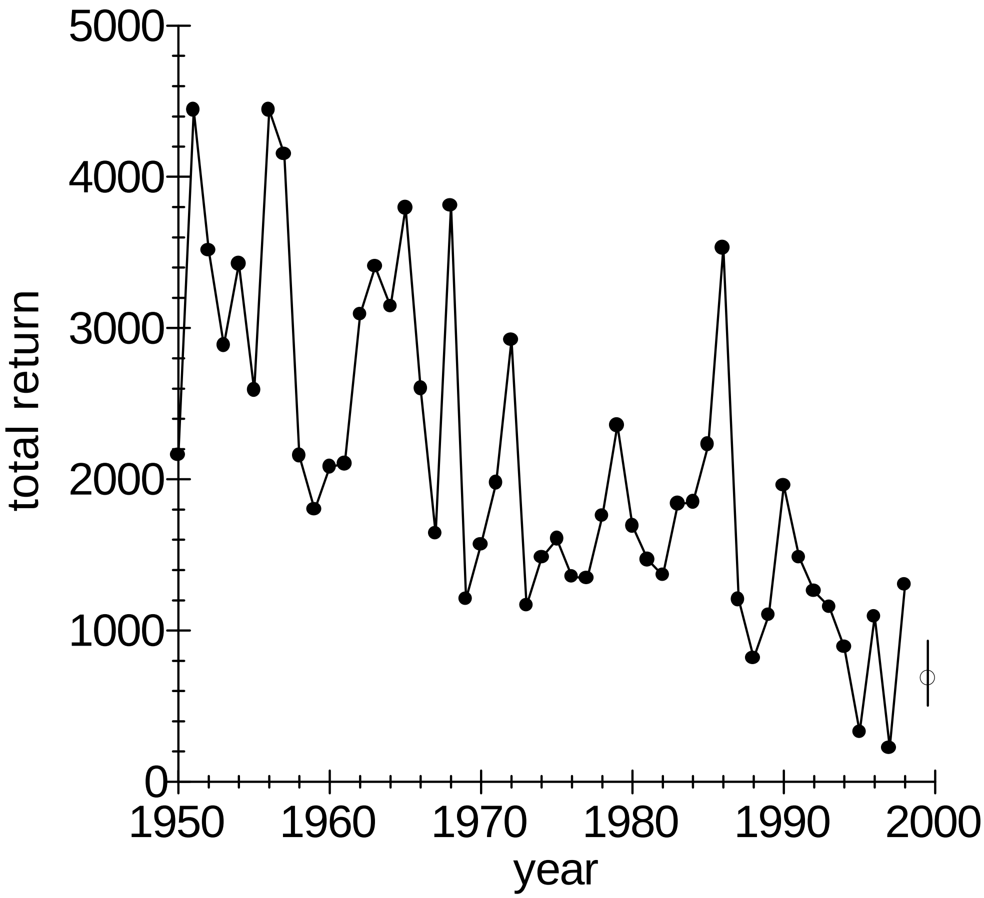

Figure 10. Total return to the average stream in Area 6. The 3YRA forecast and 50% CI are shown.

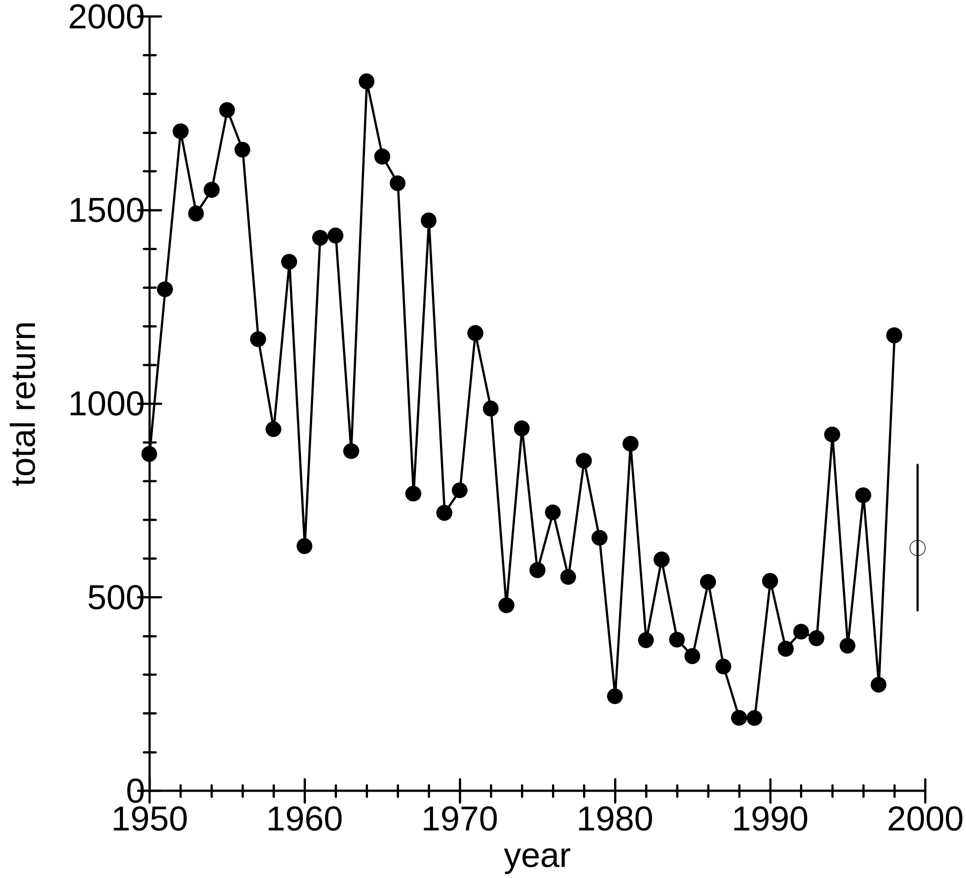

Figure 11. Total return to the average stream of the Area 7 (Bella Bella) aggregate. The 3YRA forecast and 50% CI are shown.

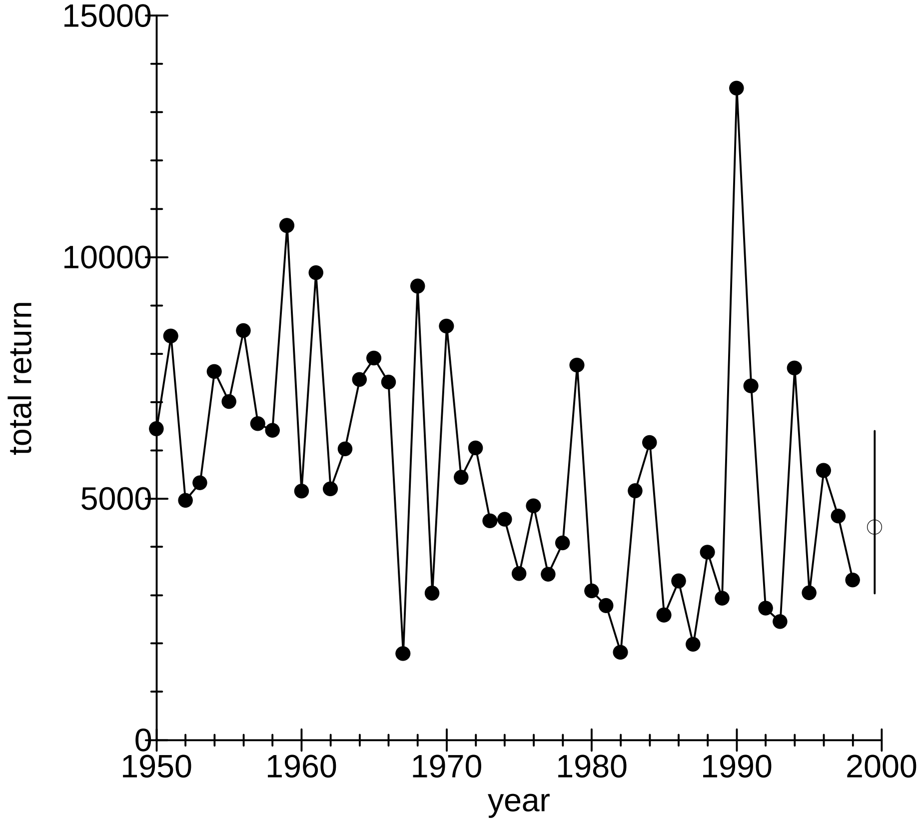

Figure 12. Total return to the average stream of the Bella Coola (Area 8) aggregate. The 3YRA forecast and 50% CI are shown.

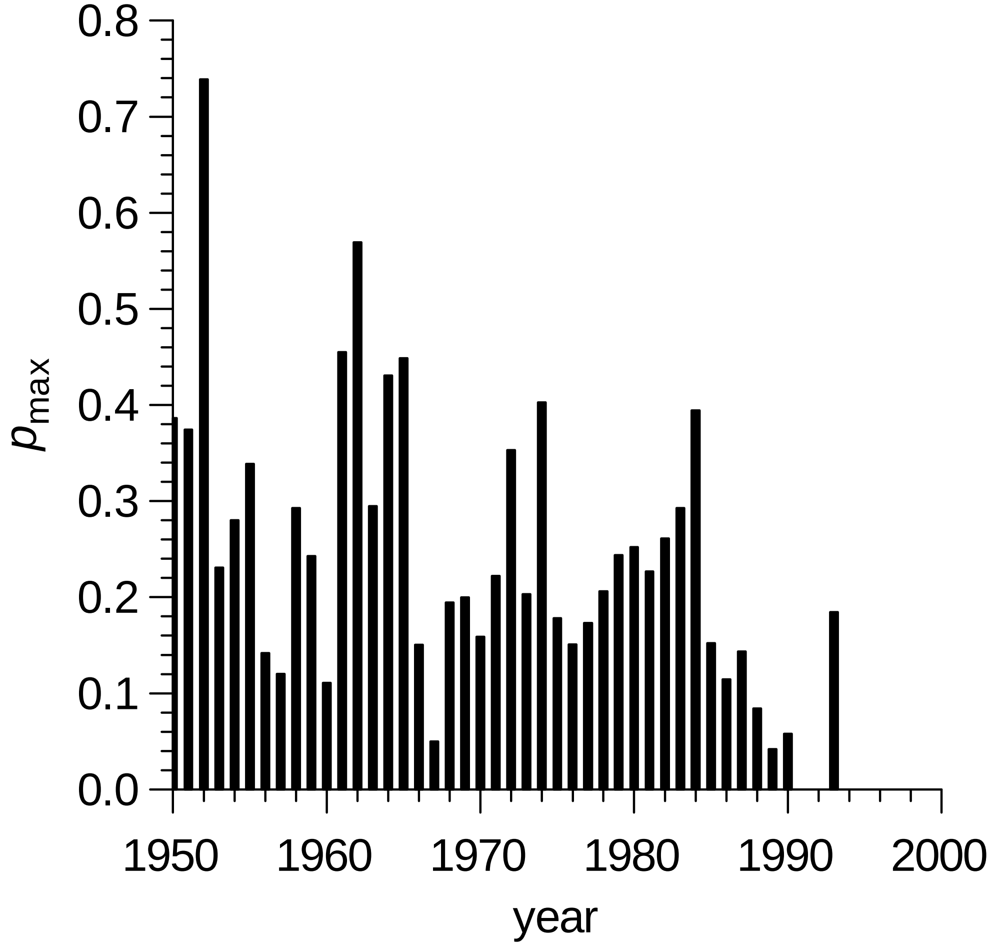

Figure 13. Standarized escapement index for the Area 9 and 10 coho aggregate of the Central Coast. There is insufficient data to enable a reconstruction of total abundance.

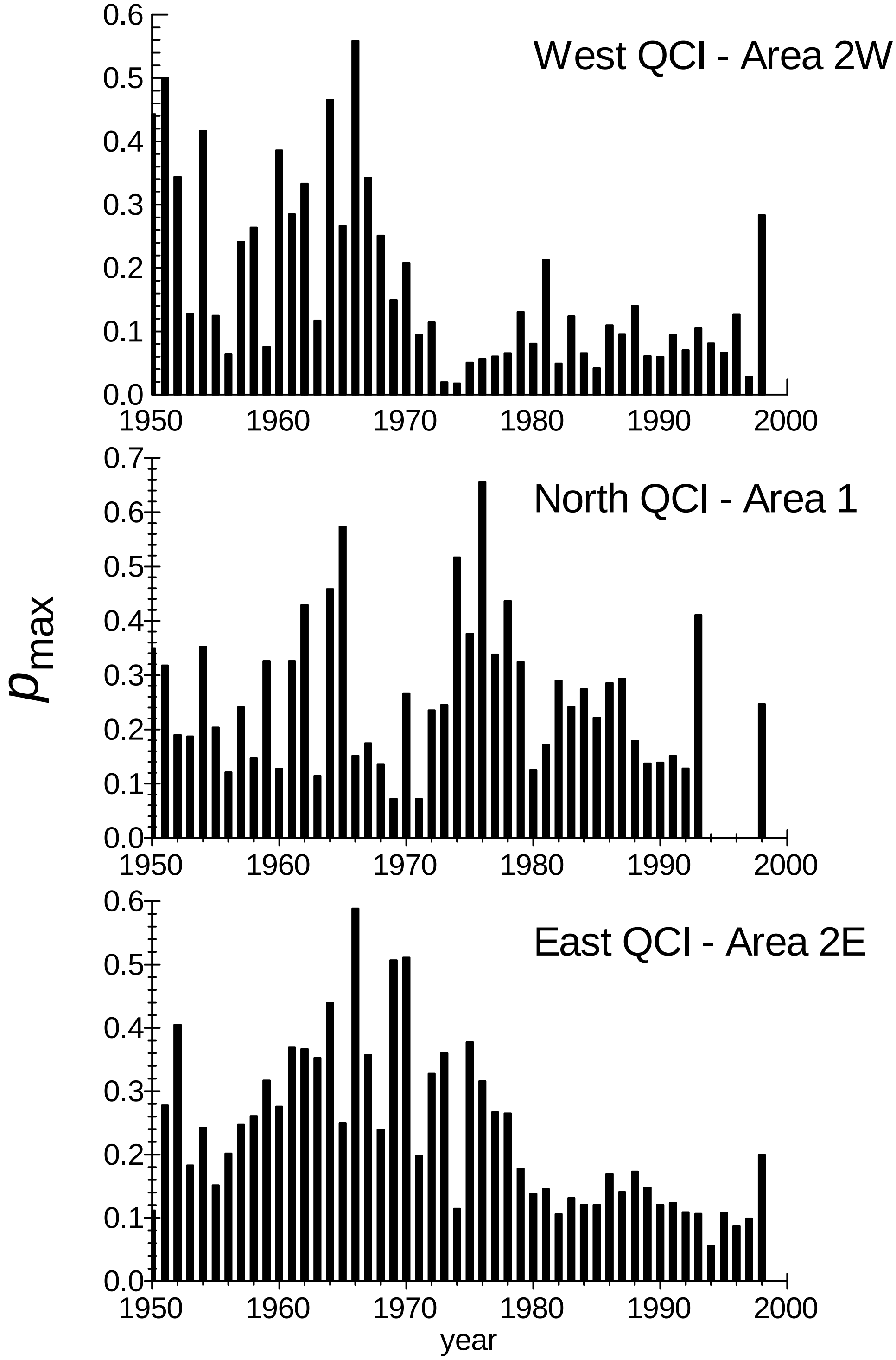

Figure 14. Standarized escapement indices for the three coho aggregates of the Queen Charlotte Islands. There is insufficient data to enable reconstructions of total abundance.