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Trends in abundance and pre-season 1999 stock size forecasts for major sockeye, pink, and chum salmon stocks in Northern British Columbia

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Abstract

This working paper includes pre-season 1999 stock size forecasts for nine sockeye, five pink, and five chum salmon stocks or stock groupings in northern British Columbia, statistical areas 1-10. The recommended forecasts are based on simple models that have been evaluated in a previous working paper.

The recent 5-yr mean model is a simple time-series approach that effectively accommodates gradual changes (autocorrelated anomalies) in productivity. For northern populations of sockeye salmon, this model has performed as well, or better than other models because variations in the independent variables used by other models have been small, and their effects have been obscured by other factors. However, for Skeena River sockeye, the 5-yr mean model should be rejected in favour of the "smolt" or "sibling age-class" models that include the effect of measured, record low smolt production in two consecutive years. Although the sibling model has not performed especially well in retrospective analyses under typical conditions, it's use is recommended for 1999 to capture the combined effects of poor freshwater production for the 1994 and 1995 brood years as well as apparent poor marine survival for the 1994 brood year. This recommendation is also consistent with the precautionary approach to fisheries management because the sibling model predicts the lowest stock size in 1999.

Résumé

Le présent document de travail comprend des prévisions d'effectifs d'avant saison pour 1999 pour neuf stocks, ou groupes de stocks, de saumon rouge, cinq de saumon rose et cinq de saumon kéta du nord de la Colombie-Britannique, dans les zones statistiques 1 à 10. Les prévisions recommandées sont fondées sur des modèles simples qui ont été évalués dans le cadre d'un document de travail précédent.

Le modèle de la moyenne des cinq dernières années est une méthode simple par séries chronologiques qui permet de traiter efficacement des changements graduels (anomalies autocorrélées) de la productivité. Dans le cas des populations de saumon rouge du nord, ce modèle a donné des résultats aussi bons, sinon meilleurs, que les autres modèles car les variations des variables indépendantes utilisées pour les autres modèles ont été petites et leurs effets ont été masqués par d'autres facteurs. Mais pour le saumon rouge de la rivière Skeena, le modèle de la moyenne quinquennale devrait être rejeté en faveur des modèles fondés sur les saumoneaux ou les classes d'âge jumelles qui tiennent compte de la production faible record de saumoneaux mesurée au cours de deux années consécutives. Bien que le modèle des classes d'âge jumelles n'ait pas donné de résultats particulièrement bons après analyses rétrospectives dans des conditions représentatives, son utilisation est recommandée pour 1999 afin de saisir les effets combinés de la faible production en eau douce des géniteurs de 1994 et 1995 de même que la faible survie en mer apparente de pour l'année de production de 1994. Cette recommandation est conforme à l'approche de prudence appliquée à la gestion des pêches, car le modèle des jumeaux est celui qui donne l'effectif de stocks le moins élevé prévu pour 1999.

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1.0 INTRODUCTION

This working paper includes pre-season 1999 stock size forecasts for nine sockeye, five pink, and five chum salmon stocks or stock groupings in northern British Columbia, statistical areas 1-10 (Fig. 1). The forecasts are based on simple methods assessed and recommended in previous working papers (Wood et al. 1995, 1996). Our approach again involves three guiding principles:

1) *The entity being forecasted must be measurable*. We did not attempt to forecast stock sizes for stocks where stock size could not be measured with reasonable accuracy. In most cases, catches in mixed-stock fisheries cannot be (or have not been) apportioned reliably to individual populations, so we were unable to forecast returns to individual populations or rivers. Exceptions include the Skeena River, Nass River, Atnarko River, Kitlope Lake, and Kimsquit Lake sockeye salmon stocks where catches have been estimated using stock reconstruction procedures (section 2.1). In other cases, we forecasted the aggregate stock size for stock groupings defined at an appropriate spatial scale (typically statistical area) such that total catch for the aggregate was known reliably. We argue that forecasts at any finer spatial scale have no value without specifying some procedure for measuring (or estimating) actual returns.

2) *A forecast should specify the probability of all possible stock sizes*. Information about the uncertainty of the forecast is more important to managers following a precautionary approach than a point estimate of the most likely stock size. Forecasts that do not include a measure of uncertainty are likely to be misleading. We argue that simple, robust forecasting methods that properly represent uncertainty are preferable to more complicated methods that do not include a measure of uncertainty.

3) *Forecasting methods should be selected for their predictive power (measured in retrospective analyses), not on how well the underlying models fit historical data.* With one exception noted below, all forecasts recommended in this working paper are based on procedures that performed best in retrospective analyses for three sockeye salmon stocks (Long Lake, Owikeno Lake, and Skeena River), one pink salmon stock (Area 8), and one chum salmon stock (Area 8) (Wood et al. 1995, 1996). Within each species, the method that performed best in the retrospective analysis was applied to additional stocks as data permitted.

Sockeye fry recruitment and smolt production in Babine Lake (Skeena River) was dramatically reduced by parasitic infections at the Babine Lake Development Project sites in 1994 and 1995 (Wood et al. 1998). To be precautionary, and to include biological information relevant to these abnormal conditions, forecasts for Skeena River sockeye in 1998 were based on the smolt and sibling age-class models rather than the 5-yr average model. These biological forecasting models are used again to forecast Skeena sockeye recruitment from brood years returning in 1999.

2.0 METHODS

2.1 Sources of Data

All data used to generate and evaluate forecasts presented in this working paper are compiled in the Appendix Tables. Data for Owikeno Lake (Area 9) sockeye, Long Lake (Area 10) sockeye, and Area 8 pink salmon are from Wood et al. (1997) updated with preliminary 1998 data provided by the responsible managers in Fisheries and Oceans, Canada (DFO).

Recent total stock size information for sockeye salmon returning to the Haida Gwaii/Queen Charlotte Islands was provided by Pat Fairweather (Haida Fisheries Program (HFP), Skidegate, B.C., pers. comm.). This information is now collected through joint HFP/DFO research funded principally through the Aboriginal Fisheries Strategy. Total catches (in food fisheries) have been recorded since 1992 for Yakoun Lake and since 1983 for Skidegate Lake. For consistency, we used foot survey estimates of escapements to Yakoun Lake throughout the time series; estimates prior to 1993 are visual estimates from the Salmon Escapement Database System (SEDS, Serbic 1991), more recent estimates involve area-under-the-curve estimation and are considered to be more reliable. Escapements to Skidegate Lake prior to 1983 are from SEDS, those from 1983 to 1993 are from a counting plate program (counts interpolated during unmonitored periods), and those since 1994 are full fence counts (no unmonitored periods).

Total stock and escapement data for Nass River (Area 3) and Skeena River (Area 4) sockeye salmon were compiled for 1970-1998 by the responsible manager (co-author L.J.). These data include reconstructed catches of Nass and Skeena sockeye salmon in mixed-stock fisheries in Alaska and northern British Columbia, based on stock reconstructions for 1982-1992 reported by Gazey and English (1996) and stock composition estimates for 1982-1983 from a joint Canada-U.S. tagging study.

Escapements of sockeye salmon to Kitlope Lake, Kimsquit Lake and the Atnarko River are taken from SEDS. Total stock sizes for these stocks were estimated very approximately as escapement/(1 - average exploitation rate) using an average exploitation rate for each stock estimated in stock reconstructions for the period 1970-1982 (Starr et al. 1984).

Total catch and escapements for pink and chum salmon by statistical area are from the DFO Commercial Salmon Catch Database (Holmes and Whitfield 1991) and SEDS, respectively. Age composition data for Area 8 chum salmon were provided by the responsible manager Lyle Enderud (DFO, Bella Coola, B.C., pers. comm.).

No forecasts are provided for pink and chum salmon stocks in statistical areas 1, 2W, 3, 4, 5, and 7. Stocks in areas 2W, 5, and 7 were excluded because catches recorded from these areas are dominated by salmon returning to larger stocks in adjacent areas. Stocks in areas 1, 3, and 4 were excluded primarily because catches in these most northern areas include a substantial proportion of pink and chum salmon returning to Alaska. No reliable method exists to apportion catches in these fisheries to stocks in the respective statistical areas (Gazey and English 1996). We concluded that total stock size could not be estimated reliably enough to warrant pre-season forecasts for any of these statistical areas.

2.2 Forecasting Models

A minimum requirement for forecasting models in this context was that forecasts for 1999 could be generated with data available at the time of analysis in early 1999. This requirement often precluded the use of sibling age class models because 1998 age composition data were not yet available. Of the ten models considered by Wood et al. (1995), five are used in this working paper. All assume lognormal error structure as generally recommended for these types of analyses (Peterman 1981; Hilborn and Walters 1992). Model parameters were estimated using SYSTAT (Wilkinson 1990).

2.2.1. *Sockeye salmon*. Following previous recommendations endorsed by PSARC, the recent 5-yr average stock size model (previously labelled *5YAVGCY*, Wood et al. 1995) with log-normal error structure was used to forecast stock sizes in 1999 for all sockeye stocks except the Kimsquit stock. The forecast for the Kimsquit stock is based on the long-term average model (previously labelled *AVGCY* and described in section 2.2.3) because no escapement data were available for three recent years (1994, 1995, and 1998).

Wood et al. (1995) concluded that average stock size methods, particularly the recent 5-yr average stock size model, rated best for sockeye stocks under the root mean square error (RMSE) criterion that they judged to be most important. Average methods also rated best in two of the three sockeye stocks under the mean absolute deviation (MAD) criterion. A practical advantage of these methods is that no biological assumptions, understanding, or sampling data are required beyond the record of numerical abundance for each calendar year. Accordingly, Welch et al. (1994) considered these models to represent a base or "zero level" of forecasting skill. On the other hand, they are "honest" and rigorous models in that they take the historical distribution of stock sizes into account, assuming only that the future will be like the past.

The 5-yr average stock size forecast is given by:

$$\mathbf{\ln(N_{t+1}) = a + \varepsilon_t}$$

where N_t is total stock size in year t, ε_t is a normal variate with mean 0 and variance σ^2, and *a* is the most recent 5-yr average = $\sum \ln(N_i)/5$ for i= t-4 to t.

Two additional, biological models were used to forecast Skeena sockeye salmon returns in 1999: The first is a non-linear stock-recruitment relationship based on observed smolt production (the "smolt" model)

$$\mathbf{\ln(R_t) = a + b\ln(J_t) + \varepsilon}$$

where R_t is the adult return and J_t is the smolt abundance for brood year t. Parameter estimates based on the entire data series are a= 5.598 and b=0.502 for R_t and J_t in millions of fish.

The second is a non-linear sibling age-class model (Bocking and Peterman 1988) based on observed returns of a younger age class from the same brood year

$$\mathbf{ln(R_{t,k+1}) = a + bln(R_{t,k}) + \varepsilon}$$

where $R_{t,k}$ is the adult return at age k in brood year t. Parameter estimates based on the entire data series are a= 5.631 and b=0.689 for predicting $R_{1995,4}$ (Skeena age 4_2 returns in millions of fish) from Babine age 3_2 returns and a= 2.325 and b=0.835 for predicting $R_{1994,5}$ (Skeena age 5_2 returns in millions of fish) from Skeena age 4_2 returns.

2.2.2 *Pink salmon*. Brood year escapement data and the non-linear Ricker stock-recruitment model (*NLSRESC*) were used to forecast pink salmon returns. This escapement model performed considerably better than the average stock size models in the retrospective analysis for Area 8 pink salmon (Wood et al. 1995). Returns (R) from a spawning escapement (S) in brood year t are given by:

$\mathbf{R_t = S_t\, e^{a + bSt}}$ where parameters *a* and *b* are estimated from

$$\mathbf{ln(R_t/S_t) = a + bS_t + \varepsilon_t}$$

2.2.3 *Chum salmon*. The long-term average stock size model model was also used to forecast all chum salmon stock sizes in 1999 because it performed as well or better than competing models in a retrospective analysis for Area 8 chum salmon (Wood et al. 1996).

The long-term average stock size forecast is given by:

$$\mathbf{ln(N_{t+1}) = a + \varepsilon_t} \qquad \text{where } a = \sum \ln(N_i)/t \quad \text{for } i=1 \text{ to } t$$

2.3. Probability Distributions for 1999 Forecasts

Probability distributions for the 1999 stock size forecasts were computed by assuming that errors in the forecasted (log-transformed) stock size are normally distributed. Forecasted stock sizes in the log-transformed domain corresponding to risk averse probability reference points of 90%, 75%, 50%, and 25% were computed from the student's *t* inverse distribution function (tif) in SYSTAT using sample means and standard deviations. Forecasted stock sizes in the log-transformed domain were then transformed back to the arithmetic scale for each probability reference point. Note that the modal (most likely) stock size in the log-transformed domain corresponds to the median (50%) value in the original arithmetic scale. Similarly, cumulative probability distribution plots were generated from the student's *t* distribution function (tcf) in SYSTAT using sample means and standard deviations in the log-transformed domain.

For the average models, standard deviations were computed from the series used to compute the forecasts (i.e., all years for the long-term average model and the most recent five years for the 5-yr average model). For the regression-based escapement, smolt, and sibling models, means and standard deviations for the forecasted log-transformed stock sizes were computed as:

$$\mathbf{E[\ln(R_t)] = a + b\,X_{1999} + \ln(X_{1999})}$$

$$\mathbf{SD[(\ln(R_t)] = s_{y.x}\{(1 + 1/n + (X_{1999} - X_{mean})^2)/ \sum(X_i - X_{mean})^2\}^{0.5}}$$

where *a* and *b* are the regression parameters, $s_{y.x}$ is the standard error of the estimate, X_{1999} is the independent variable (i.e., spawning escapement for the brood returning in 1999), X_{mean} is the average value of the independent variable, and n is the number of data points in the regression (Draper and Smith, 1966).

3.0 RESULTS

3.1 Trends in Stock Size

3.1.1 *Sockeye salmon*. Escapement accounts for most of the total stock in Yakoun and Skidegate lakes in recent years. In response to concerns about declining escapements to both lakes, fishing effort (and catch) have been restricted since 1993 under management plans developed by the Council of Haida Nations in consultation with DFO. Escapement and stock size in both lakes have generally increased since 1993 and are now close to the long-term (geometric) mean (Figure 2A).

Escapements to the Skeena and Nass rivers generally met or exceeded targets during the last decade and total stock size generally exceeded the long-term mean with record high levels achieved in 1992-93 (Nass) and 1996 (Skeena). As forecast, however, the total stock of Skeena sockeye fell to record low levels in 1998 and the escapement target was not achieved. The total stock of Nass sockeye also declined in 1998 but remained near the long-term (geometric) mean and the escapement target was exceeded.

Escapements (and hence computed total runs sizes) for the Kitlope, Kimsquit, and Atnarko stocks show no obvious trend. Escapements in 1998 were above the long-term (geometric) mean in the Kitlope stock and below (but close to) the long-term mean in the Atnarko stock.

Total sockeye stocks in Owikeno and Long lakes have declined dramatically since 1992. Escapements to both lakes are now at or near record low levels, despite the fact that commercial fisheries on these stocks have been closed since 1996 (Owikeno) or 1997 (Long). This decline has been attributed to very poor marine survival for all brood years since 1990 (Rutherford et al. 1998). Escapements had been generally increasing until 1991 in Owikeno Lake, and until 1992 in Long Lake; similarly, indices of juvenile (freshwater) production for both lakes had been near historical levels until after escapements fell well below targets *as a result of* poor marine survival (Rutherford et al. 1995, 1998; Anon 1996). Survival of smolts entering the ocean in 1996 (brood year 1994) was especially poor judging by the low numbers of age 4 adults returning to both Owikeno and Long lakes in 1998.

3.1.2 *Pink salmon*. Even-year pink salmon abundance reached peak abundance in the early 1980s in all areas. Total stock sizes in areas 2E, 6, and 10 have generally decreased over the last decade and are now below long-term (geometric) mean levels (Figure 2B). In contrast, total stock sizes in areas 8 and 9 have been increasing and now exceed long-term (geometric) mean levels.

3.1.3 *Chum salmon*. Chum salmon abundance also peaked in the late 1980s in most areas, declined in the early 1990s, then increased to intermediate levels by 1995 (Figure 2C). Total stock sizes declined in 1996 and 1997 in areas 8 to10, but increased in 1998 for all areas except Area 10.

3.2 Performance of 1998 Forecasts for Sockeye Salmon

Pre-season forecasts of sockeye stock sizes in 1998 (based on the same methods used to forecast stock sizes in 1999, section 2.2), are compared with preliminary estimates of actual stock sizes in Table 1. Actual stock size was below the recommended median forecast in 5, and above the median forecast in 3 of the 8 comparisons. Percentage deviations (error) from the median forecasts ranged from –210%, because of record low abundance in the Owikeno stock, to +33% for the Skidegate stock. The observed Owikeno stock size fell within the 9th percentile of the 1998 forecast distribution, and thus, just outside the 90% confidence interval. In all other cases, observed stock sizes fell within the 90% confidence interval of the recommended forecasts. On the other hand, the 5-yr average forecast (not recommended) greatly overestimated Skeena sockeye stock size in 1998 with an error of -318%; the probability of this or smaller stock sizes under the forecast distribution was less than 0.001.

3.3 Forecasts for 1999

3.3.1 *Alternative forecasts for Skeena sockeye salmon.* Forecasts of Skeena River sockeye salmon returns in 1999 from three alternative models are summarized in Table 2. As expected, the 5-yr average stock size model predicts a median stock size of 3.2 million sockeye, above the long-term (geometric) mean. In contrast, the smolt model, endorsed by PSARC in 1998, predicts a median stock size of 1.0 million sockeye reflecting the poor smolt (freshwater) production from two consecutive brood years (Fig. 3). The sibling year-class model predicts a median stock size of only 0.6 million sockeye (Fig. 4). The smolt and sibling predictions are very similar for the 1995 brood year, but the sibling model predicts somewhat lower contributions for the 1994 brood year. Overall, the congruence of these models provides another clear signal that stock size in 1999 will be much lower than before 1998.

The 5-yr average model has performed as well or better than other models under typical situations where variation in the independent variables used by other models has been small, and their effects have been obscured by other factors. In the present case, however, the independent variables in the alternative models are at or near the extreme low end of their historical ranges. Therefore, as for the 1998 forecast, we recommend that the 5-yr average model be rejected in favour of the biological models that can include our knowledge of the abnormally low freshwater production.

Although the sibling model has not performed especially well in retrospective analyses (Wood et al. 1995), it is recommended in the present case because its predictions reflect the combined effects of poor freshwater production from two consecutive brood years, and probable poor marine survival for the 1994 brood year (see Discussion). This recommendation is also consistent with the precautionary approach to fisheries management because the sibling model predicts the lowest stock size in 1999.

3.3.2 *Recommended forecasts.* Recommended pre-season stock size forecasts for 1999 are summarized in Table 3 for four probability reference points. Actual stock sizes are predicted to exceed the median (50%) forecast reference point 50% of the time (i.e., 1 time out of 2). The other reference points are provided to facilitate risk averse management decisions. Actual stock sizes are predicted to exceed the lowest (90%) reference point 9 times out of 10, and to exceed the intermediate (75%) reference point, 3 times out of 4. The full cumulative probability distribution for these forecasts is presented graphically in comparsions with historical returns in Figures 5 (sockeye salmon), 6 (pink salmon), and 7 (chum salmon).

4.0 DISCUSSION

Previous evaluations of forecasting performance for northern BC salmon stocks have demonstrated that simple average models can work as well or better than those incorporating biological data (Wood et al. 1995, 1996). Biological relationships such as stock-recruitment relationships often explain a statistically significant amount of variation in historical data, reflecting real biological processes that should be considered in decisions involving *average* levels of productivity. However, they typically explain only a small fraction of the total variation in survival observed from brood to brood in northern BC stocks. This may be because the observed range of variation in the biological variables has been small in northern stocks. Also, uncertainty in predicting age at maturation in northern sockeye and chum salmon stocks introduces error when developing forecasts of total stock size in a calendar year from forecasts of returns by brood year. Even so, the smolt and sibling year class models correctly predicted the low abundance of Skeena sockeye in 1998 where the 5-yr average model did not (Table 1). Clearly, these biological models can be effective given adequate contrast in the independent variables.

Although overall marine survival cannot yet be computed for the 1994 brood year, the congruence in rates of return for ages 3 and 4 implies that marine survival was well below average (Fig. 8). A similar pattern of poor survival of smolts entering the ocean in 1996 is emerging for a number of stocks for which survival data is considered reasonably reliable. Examples include Nass, Long and Owikeno sockeye (Fig. 9) and coho salmon returning in 1997 throughout northern BC (Holtby and Finnegan 1997). On the other hand, the strength of age 3 returns from the 1995 brood year suggests that subsequent marine survival has returned to above average levels (Fig. 8).

5.0 REFERENCES

Anon. 1996. Integrated fisheries management plan, Rivers Inlet sockeye salmon. Unpubl. report, Fisheries and Oceans, Canada, 555 W. Hastings St., Vancouver, B.C., 37 p.

Bocking, R.C., and R.M. Peterman. 1988. Preseason forecasts of sockeye salmon (*Oncorhynchus nerka)*: Comparison of methods: and economic considerations. Canadian Journal of Fisheries and Aquatic Sciences 45:1346-1354.

Draper, N.R., and H. Smith. 1966. Applied regression analysis. J. Wiley & Sons, Inc., New York.

Gazey, W.J., and K.K. English. 1996. Assessment of sockeye and pink salmon stocks in the northern boundary area using run reconstruction techniques, 1982-92. PSARC Working Paper S96-04.

Hilborn, R., and C.J. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman and Hall, New York.

Holmes, M.A., and D.W.A. Whitfield. 1991. User's manual for the commercial salmon catch spreadsheet program. Canadian Technical Report of Fisheries and Aquatic Sciences 1807:44 p.

Holtby, L.B., and B. Finnegan. 1997. A biological assessment of the coho salmon of the Skeena River, British Columbia, and the recommendations for fisheries in 1998. PSARC Working Paper S97-12.

Peterman, R.M. 1981. Form of random variation in salmon smolt-to-adult relations and its influence on production estimates. Canadian Journal of Fisheries and Aquatic Sciences 38:1113-1119.

Rutherford, D.T., S. McKinnell, C.C. Wood, K.D. Hyatt, and R. Goruk. 1995. Assessment of the status of Rivers Inlet sockeye salmon. PSARC Working Paper S95-5.

Rutherford, D.T., C.C. Wood, and S. McKinnell. 1998. Rivers Inlet Sockeye Salmon: Stock Status Update. Canadian Stock Assessment Secretariat Research Document 98/91

Starr, P.J., A.T. Charles, and M.A. Henderson. 1984. Reconstruction of British Columbia sockeye salmon (*Oncorhynchus nerka*) stocks: 1970-1982. Can. Man. Rep. Fish. Aquat. Sci. 1780: 123 p.

Serbic, G. 1991. The salmon escapement database reporting system. Canadian Technical Report of Fisheries and Aquatic Sciences 1791:104 p.

Welch, D.W., H.M.C. Kelly, and W. Saito. 1994. An assessment of recruitment forecast methods for Fraser River sockeye salmon, with forecasts for 1994, 1995, and 1996. PSARC Working Paper S94-16

Wilkinson, L. 1990. Systat. Systat,Inc. Evanston, IL.

Wood, C.C., D.T. Rutherford, D. Bailey, and M. Jakubowski. 1998. Assessment of sockeye salmon production in Babine Lake, British Columbia with forecast for 1998. Can. Tech. Rep. Fish. Aquat. Sci. 2241: 50 p.

Wood, C.C., D.T. Rutherford, D. Peacock, and S. Cox-Rogers. 1995. Assessment of recruitment forecasting methods for selected salmon stocks in northern British Columbia. PSARC Working Paper S95-12.

Wood, C.C., D.T. Rutherford, D. Peacock, and S. Cox-Rogers. 1996. Pre-season 1997 run size forecasts for major sockeye, pink, and chum salmon stocks in northern British Columbia. PSARC Working Paper S96-20.

Wood, C.C., D.T. Rutherford, D. Peacock, S. Cox-Rogers and L. Jantz. 1997. Assessment of recruitment forecasting methods for major sockeye salmon and pink salmon stocks in northern British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 2187: 85 p.

Table 1. Comparison of pre-season forecasts and observed stock sizes for sockeye salmon in 1998. Observed values are preliminary estimates.

Area	Stock	Method	Run Size (thousands of fish) median forecast	observed (preliminary)	forecast error[a]	percent error	Probability of greater deviation[b]
1	Yakoun	*5-yr average*	8	7	-1	-14%	0.430
2E	Skidegate	*5-yr average*	10	15	5	33%	0.218
3	Nass	*5-yr average*	950	569	-381	-67%	0.125
4	Skeena	*smolt*	1420	1040	-380	-37%	0.338
		5-yr average[c]	4350	1040	-3310	-318%	**<0.001**
6	Kitlope	*5-yr average*	38	44	6	14%	0.359
8	Atnarko	*5-yr average*	52	55	3	5%	0.463
8	Kimsquit	*average*	20				
9	Owikeno	*5-yr average*	161	52	-109	-210%	0.094
10	Long	*5-yr average*	103	76	-27	-36%	0.394

Notes:
[a] observed stock size - median forecast
[b] probability of a greater absolute deviation from median forecast under the forecast probability distribution
[c] not recommended; included only for comparison

Table 2. Comparison of pre-season stock size forecasts for Skeena River sockeye salmon in 1999 based on three alternative models. The target escapement for the Skeena River is 1,159,011 sockeye.

Model	Brood Year	Forecasts for reference probabilities **50%**	75%	90%
5-yr average	combined	**3,199,020**	1,866,384	1,049,012
smolt	1994	649,751	446,607	316,908
	1995	393,373	265,128	184,781
	combined[a]	**1,012,426**	682,370	475,584
sibling	1994	104,248	65,355	42,713
	1995	473,315	335,359	245,048
	combined[b]	**577,529**	409,177	298,940

Notes

[a] based on 45% returning at age 4 and the pooled estimate of variance

[b] based on estimate of variance for brood year expected to contribute the most returns (1995)

Table 3. Summary of recommended pre-season stock size forecasts for 1999. Bold print is used to flag stock size forecasts that are well below escapement targets in stocks whose status has been reviewed previously by PSARC.

Species	Statistical Area	River or Lake	Escapement Target	Forecasts for reference probabilities[a] 25%	50%	75%	90%	Forecasting Model
Sockeye	1	Yakoun	[b]	12,000	9,000	7,000	5,000	*5-yr average*
	2	Skidegate	9,525	17,000	11,000	7,000	4,000	*5-yr average*
	3	Nass	246,000	942,000	767,000	624,000	501,000	*5-yr average*
	4	**Skeena**	**1,159,011**	**839,000**	**578,000**	**409,000**	**299,000**	*sibling*
	6	Kitlope	20,000	52,000	42,000	35,000	28,000	*5-yr average*
	8	Atnarko	75,000	81,000	59,000	44,000	31,000	*5-yr average*
	8	Kimsquit	30,000	32,000	20,000	12,000	8,000	*average*
	9	**Owikeno**	**200,000**[c]	**175,000**	**108,000**	**66,000**	**39,000**	*5-yr average*
	10	**Long**	**200,000**	**107,000**	**70,000**	**46,000**	**29,000**	*5-yr average*
Pink	2E	all	720909[e]	11,000	5,000	2,000	1,000	*Ricker* [d]
	6	all	1,447,200	1,500,000	766,000	390,000	209,000	*Ricker*
	8	all	1,475,400	2,806,000	1,663,000	983,000	604,000	*Ricker*
	9	all	342,450	472,000	162,000	55,000	20,000	*Ricker*
	10	all	65,600	15,000	7,000	3,000	1,000	*Ricker*
Chum	2E	all	453,025	498,000	318,000	203,000	135,000	*average*
	6	all	518,350	429,000	269,000	169,000	110,000	*average*
	8	all	267,450	647,000	432,000	289,000	199,000	*average*
	9	all	150,700	74,000	41,000	23,000	13,000	*average*
	10	all	98,500	64,000	37,000	21,000	13,000	*average*

[a] probability that the actual stock size will exceed the specified forecast
[b] 5000-10000 (under review)
[c] minimum; target increases with run size according to management plan.
[d] *NLSRESC* model of Wood et al. (1995).
[e] target reflects potential based on abundance of even-year pink salmon.

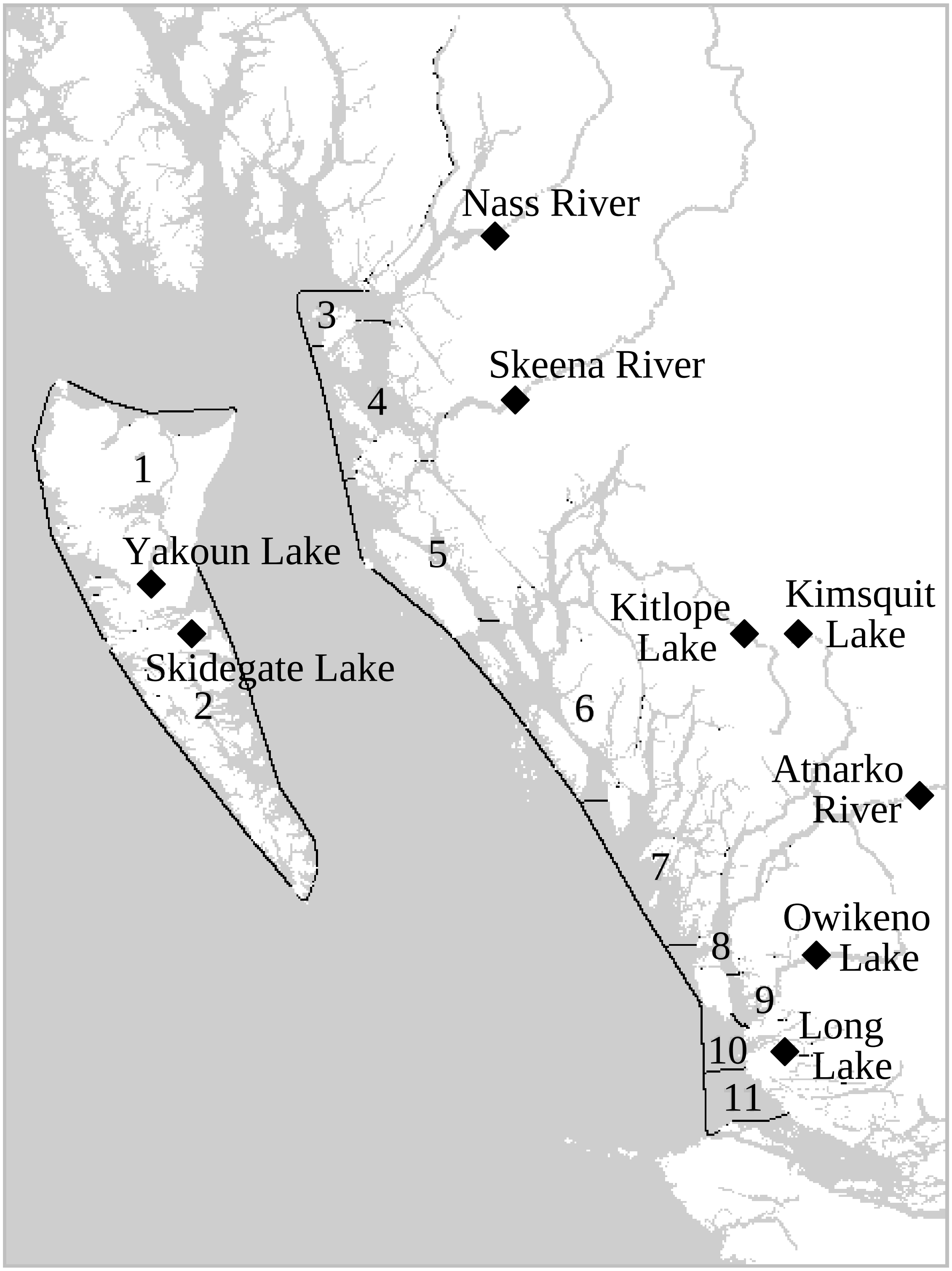


Figure 1. Map of northern British Columbia showing locations of salmon stocks and statistical areas.

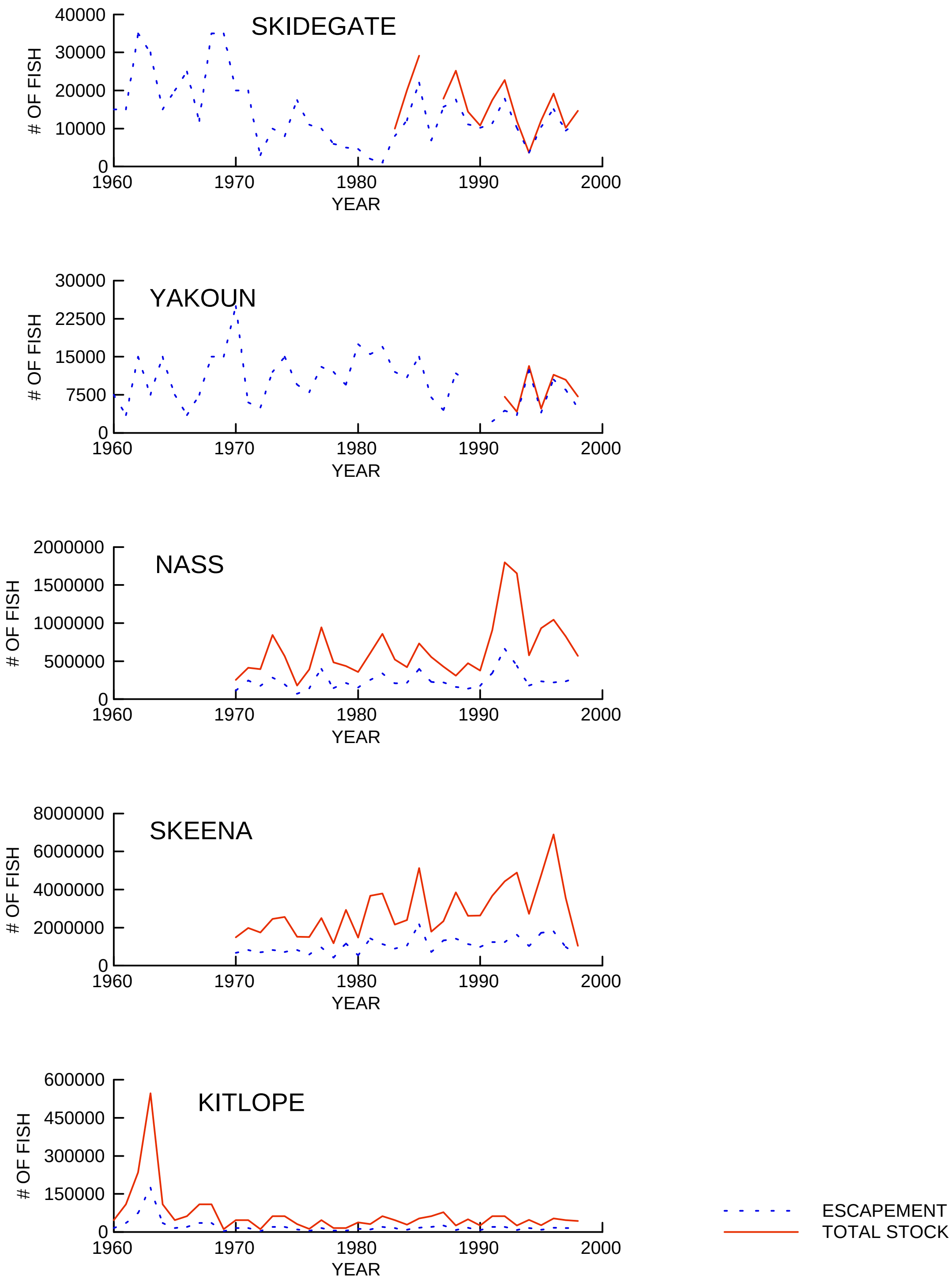


Figure 2A. Trends in spawning escapement and total stock size for sockeye salmon stocks.

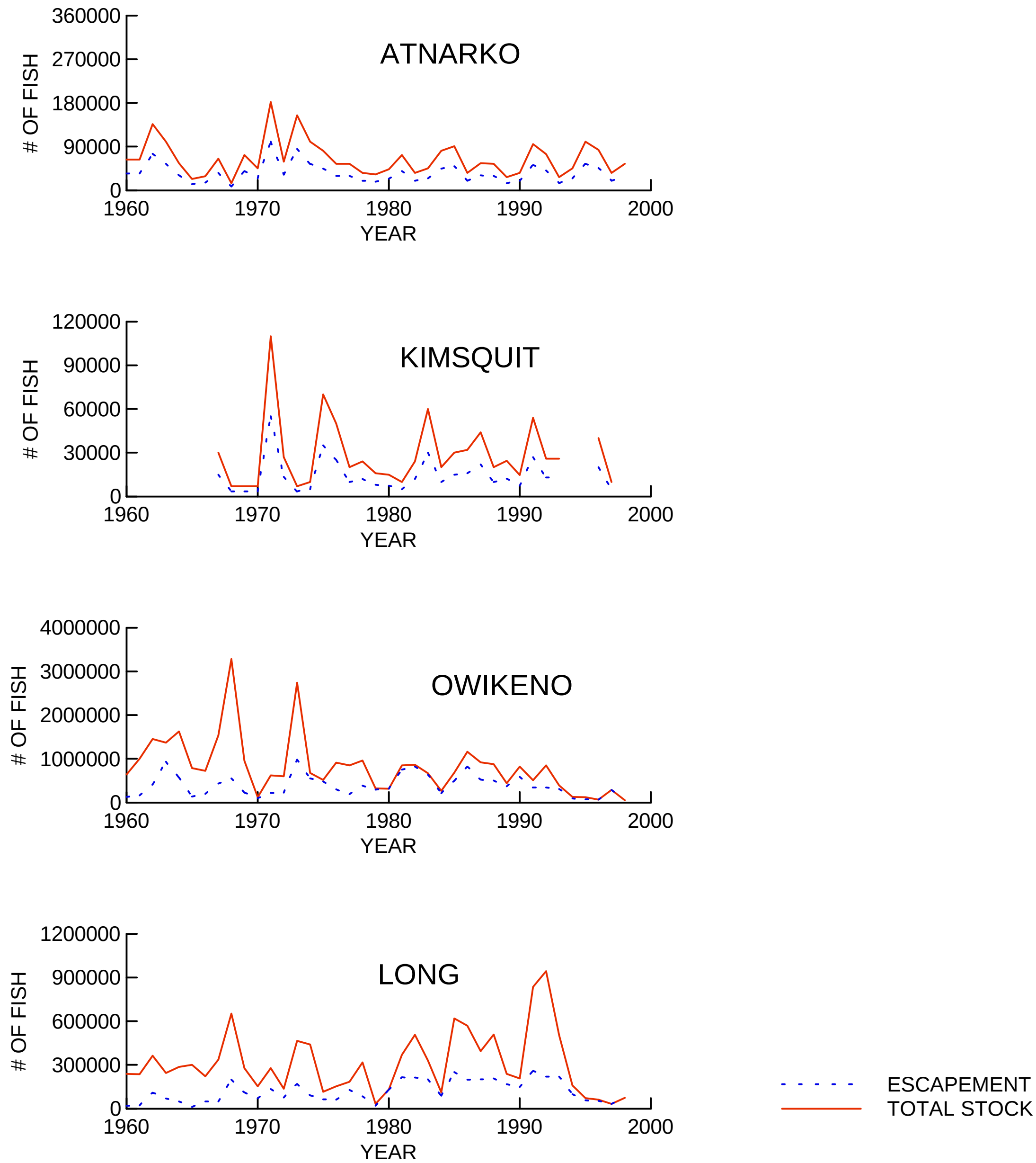


Figure 2A. (cont'd)

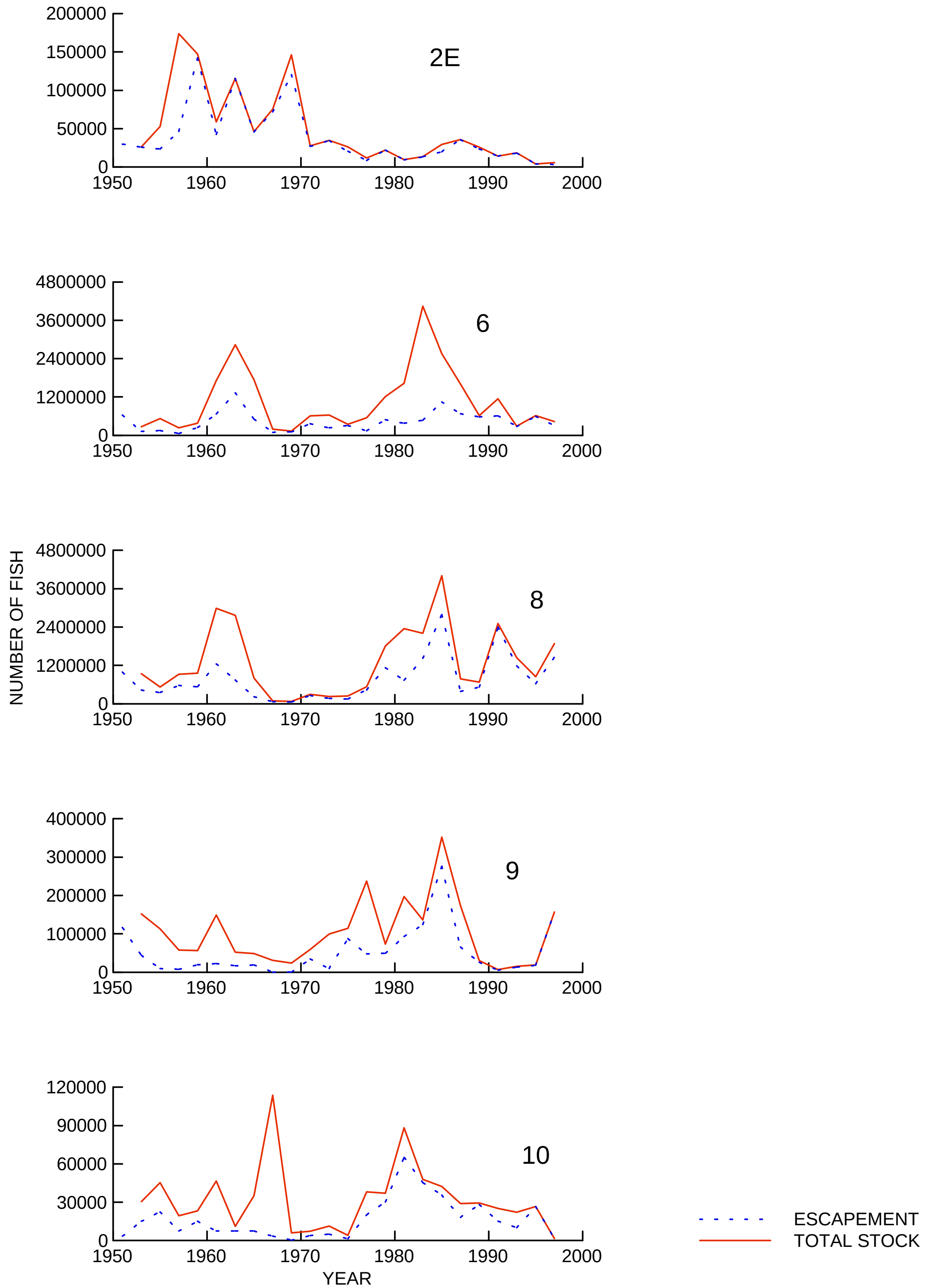


Figure 2B. Trends in spawning escapement and total stock size for odd-year pink salmon stocks

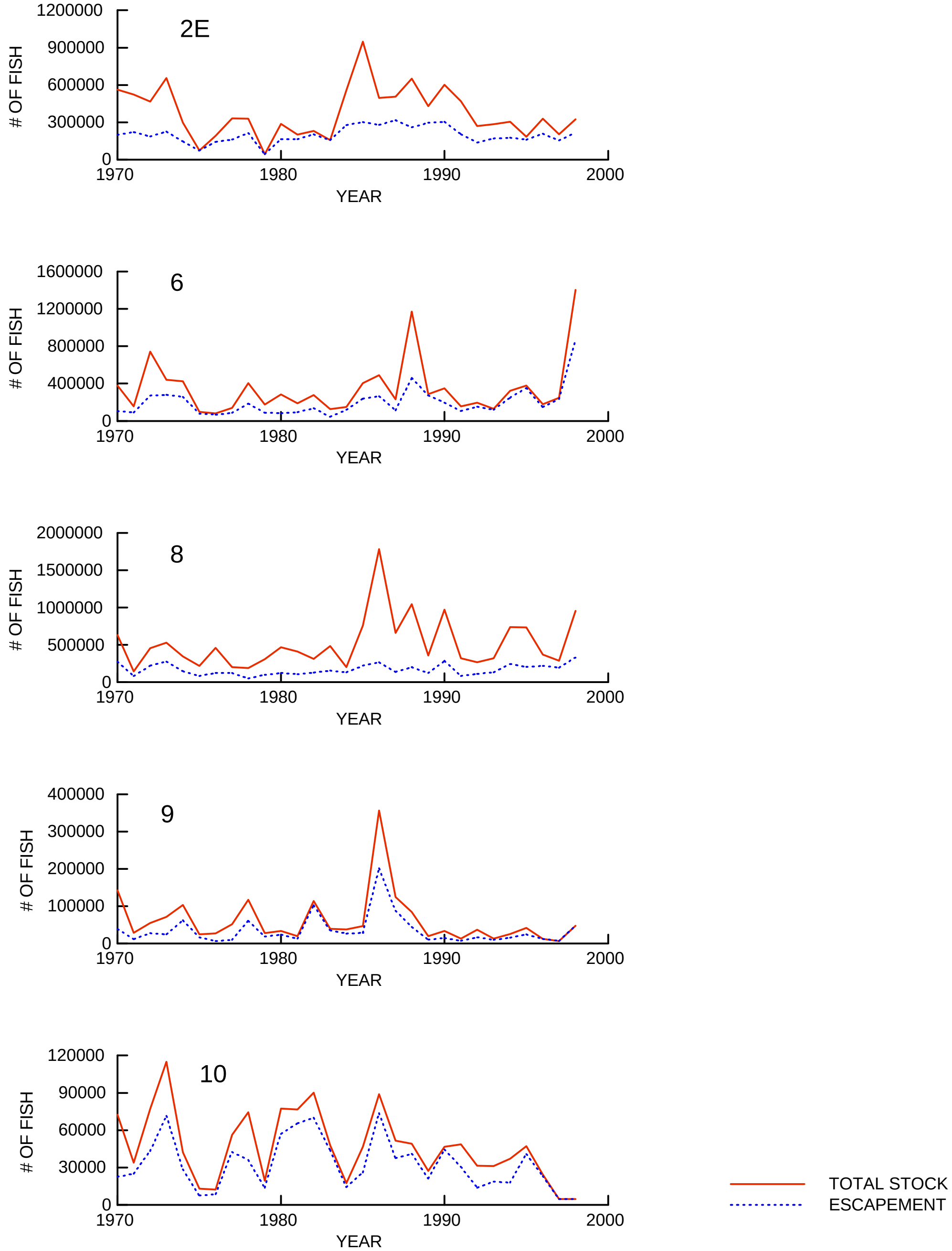


Figure 2C. Trends in spawning escapement and total stock size for chum salmon.

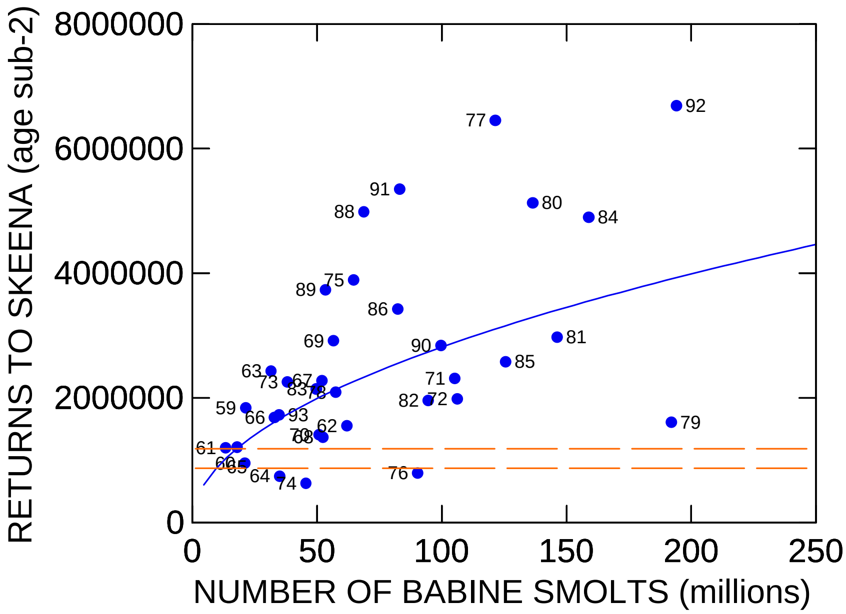


Figure 3. Model for forecasting total returns of age sub-2 Skeena sockeye from Babine smolt abundance. Dashed lines indicate low total returns expected from poor smolt production from brood years 1994 and 1995; all labels refer to brood years.

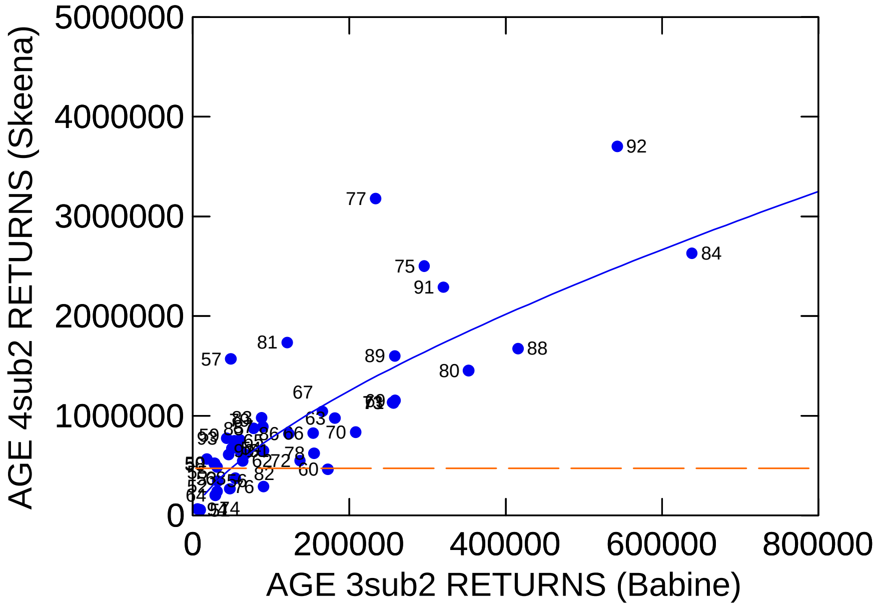


Figure 4A. Sibling model for forecasting total returns of age 4_2 Skeena sockeye from age 3_2 ("jack") returns from the same brood year enumerated at the Babine fence. Dashed lines indicate total returns expected given observed jack returns from brood year 1995; all labels refer to brood years.

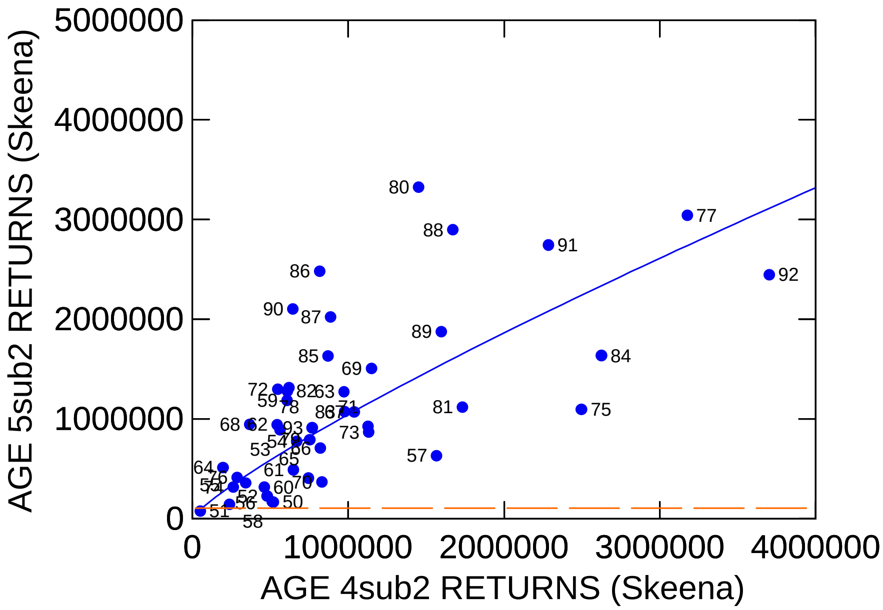
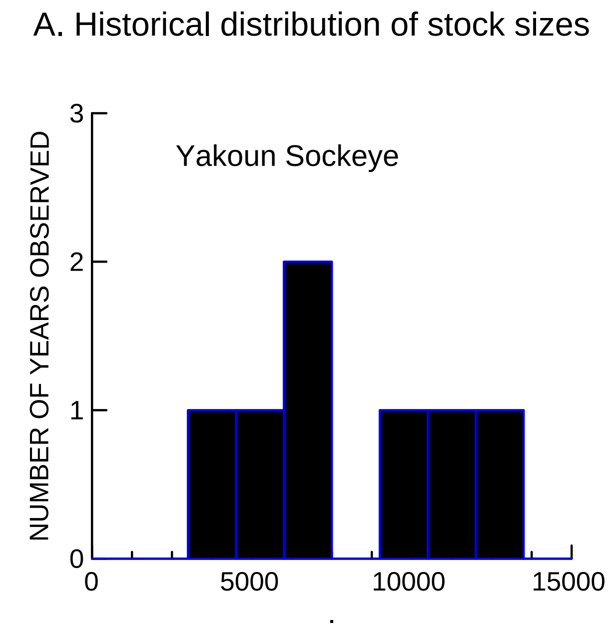


Figure 4B. Sibling model for forecasting total returns of age 5_2 Skeena sockeye from age 4_2 returns from the same brood year. Dashed lines indicate very low age 5_2 returns expected given poor age 4_2 returns from brood year 1994; all labels refer to brood years.



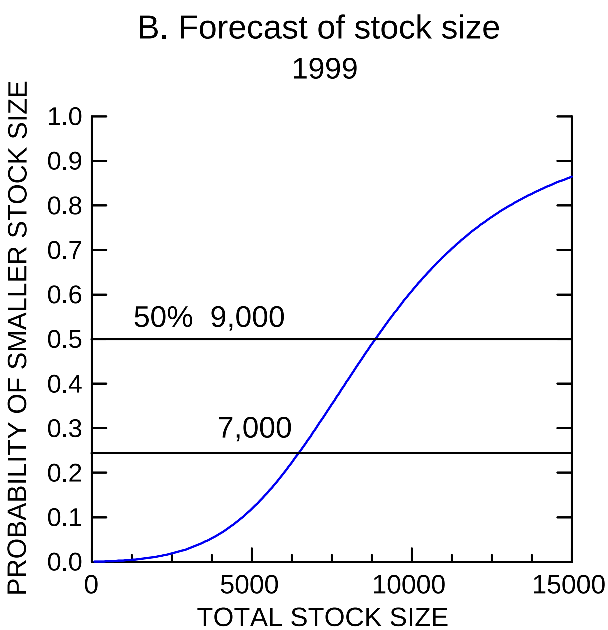
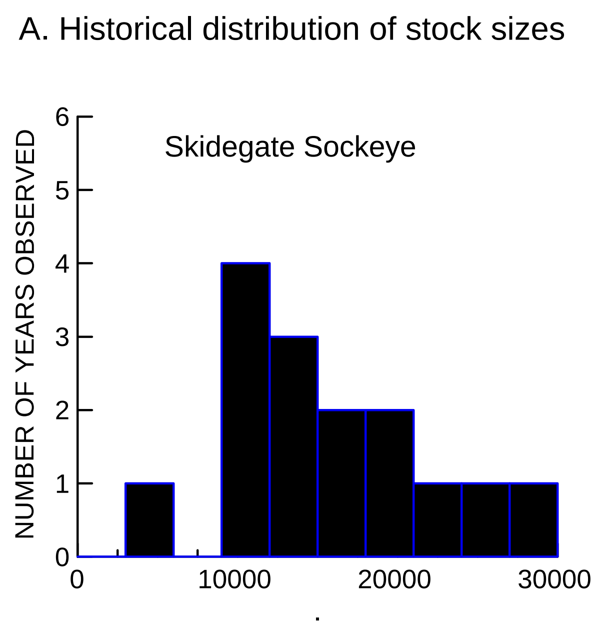


Figure 5A. The forecasted cumulative probability distribution for total stock size in 1999 for **Yakoun Lake sockeye** salmon as compared with the historical distribution of total stock size.



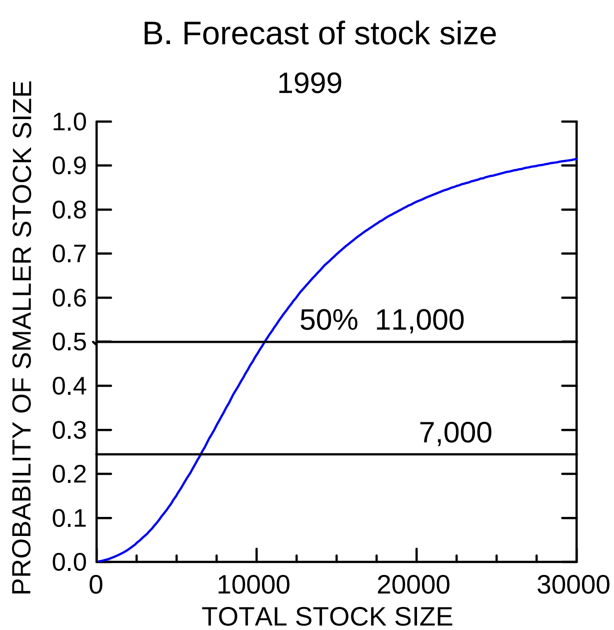


Figure 5B. The forecasted cumulative probability distribution for total stock size in 1999 for **Skidegate Lake sockeye** salmon as compared with the historical distribution of total stock size.

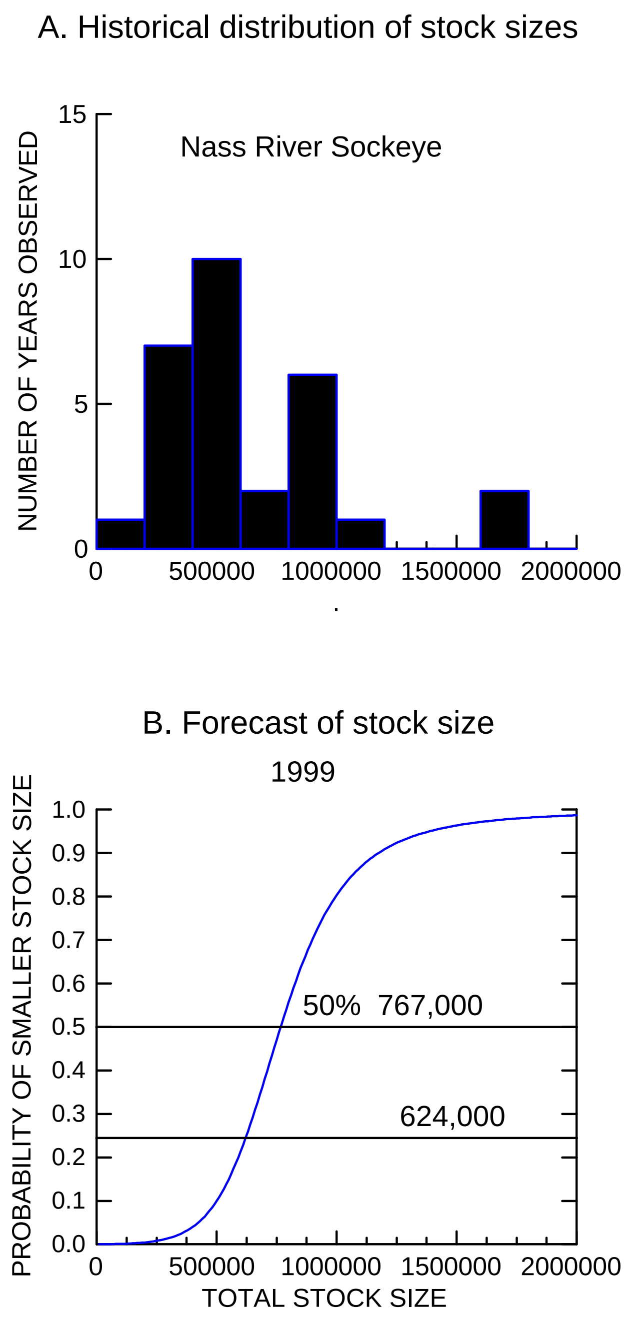


Figure 5C. The forecasted cumulative probability distribution for total stock size in 1999 for **Nass River sockeye** salmon as compared with the historical distribution of total stock size.

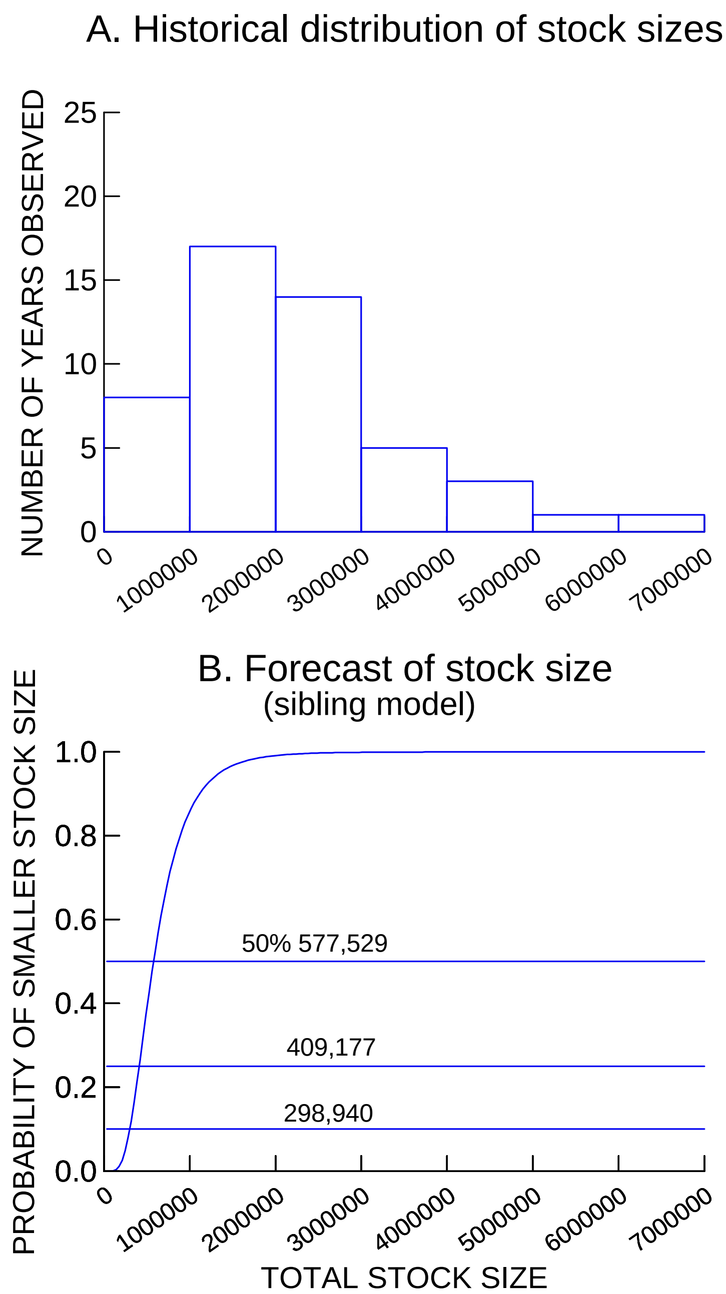


Figure 5D. The forecasted cumulative probability distribution for total stock size in 1999 for **Skeena River sockeye** salmon as compared with the historical distribution of total stock size.

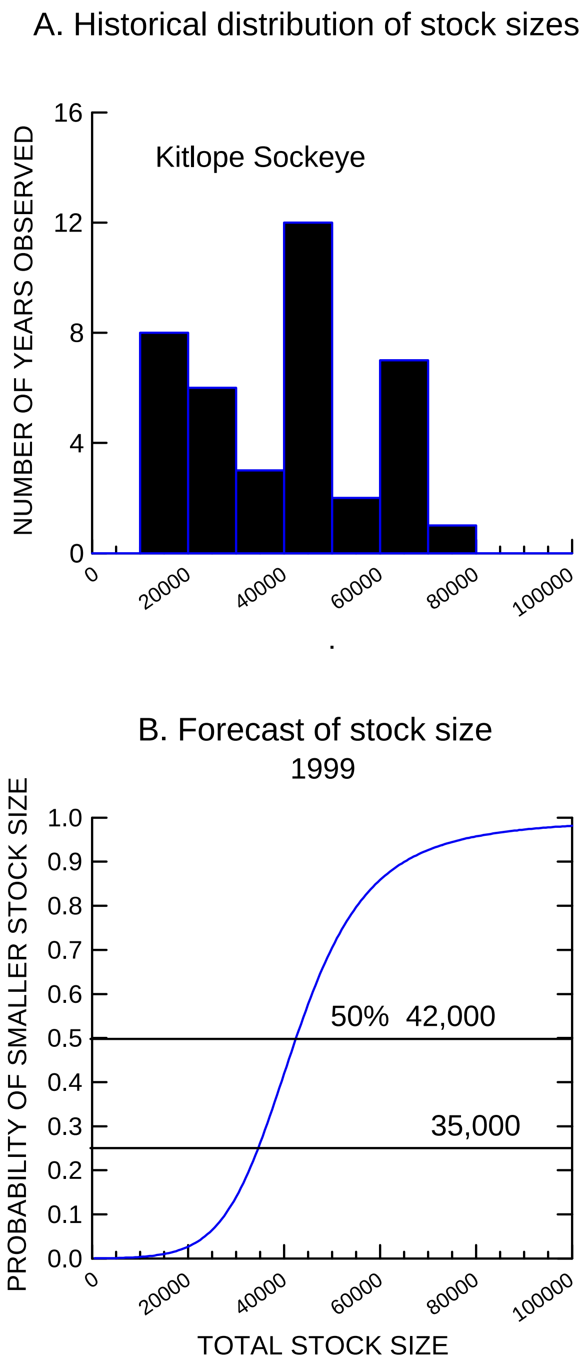
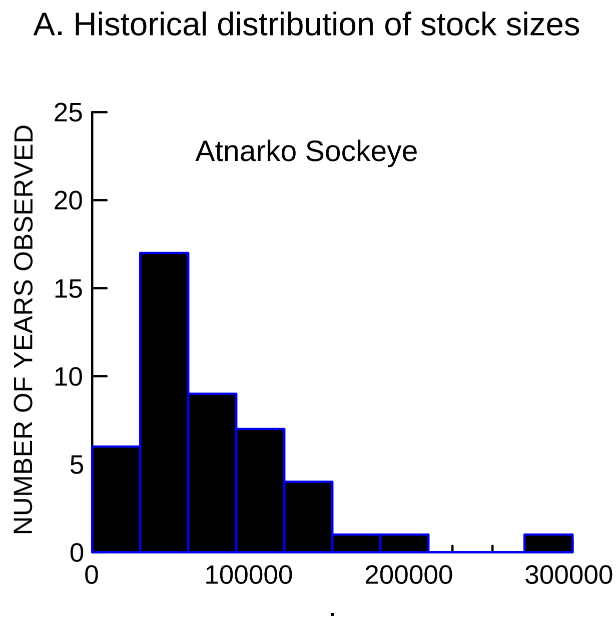


Figure 5E. The forecasted cumulative probability distribution for total stock size in 1999 for **Kitlope Lake sockeye** salmon as compared with the historical distribution of total stock size.



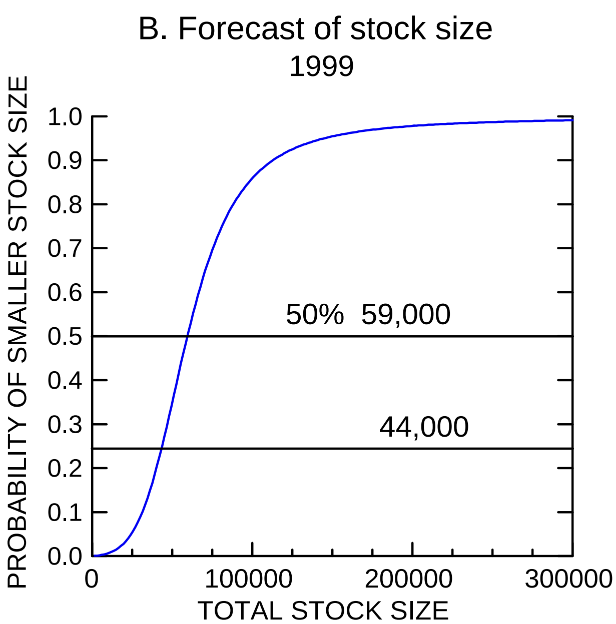


Figure 5F. The forecasted cumulative probability distribution for total stock size in 1999 for **Atnarko River sockeye** salmon as compared with the historical distribution of total stock size.

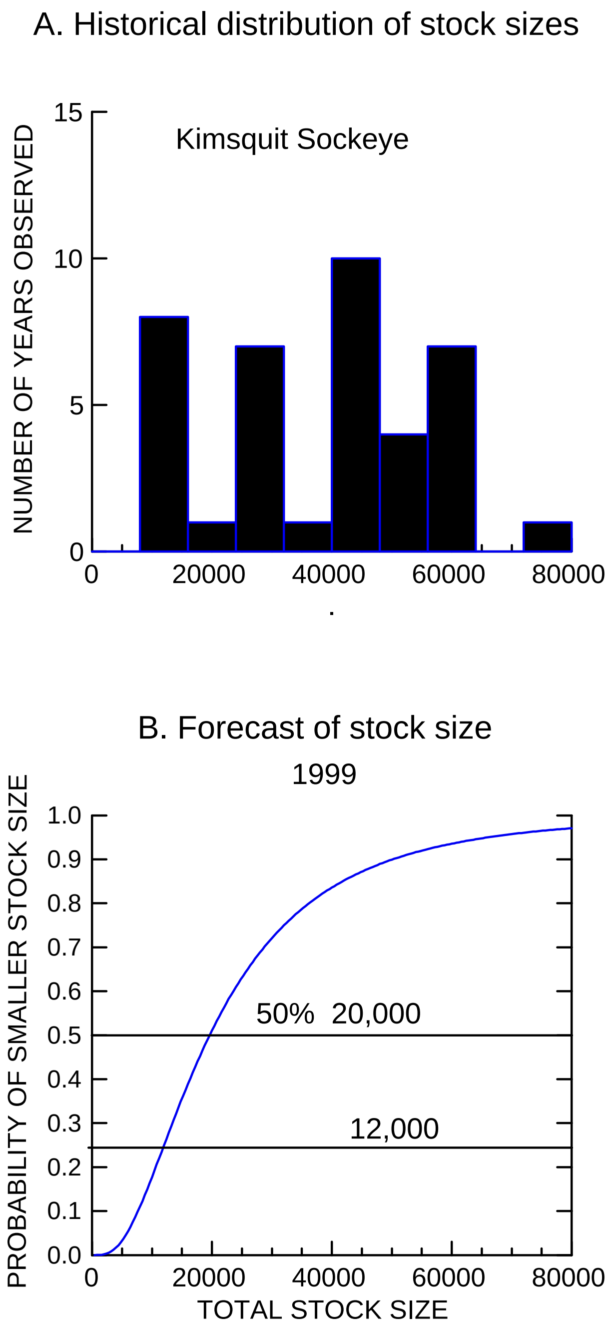


Figure 5G. The forecasted cumulative probability distribution for total stock size in 1999 for **Kimsquit Lake sockeye** salmon as compared with the historical distribution of total stock size.

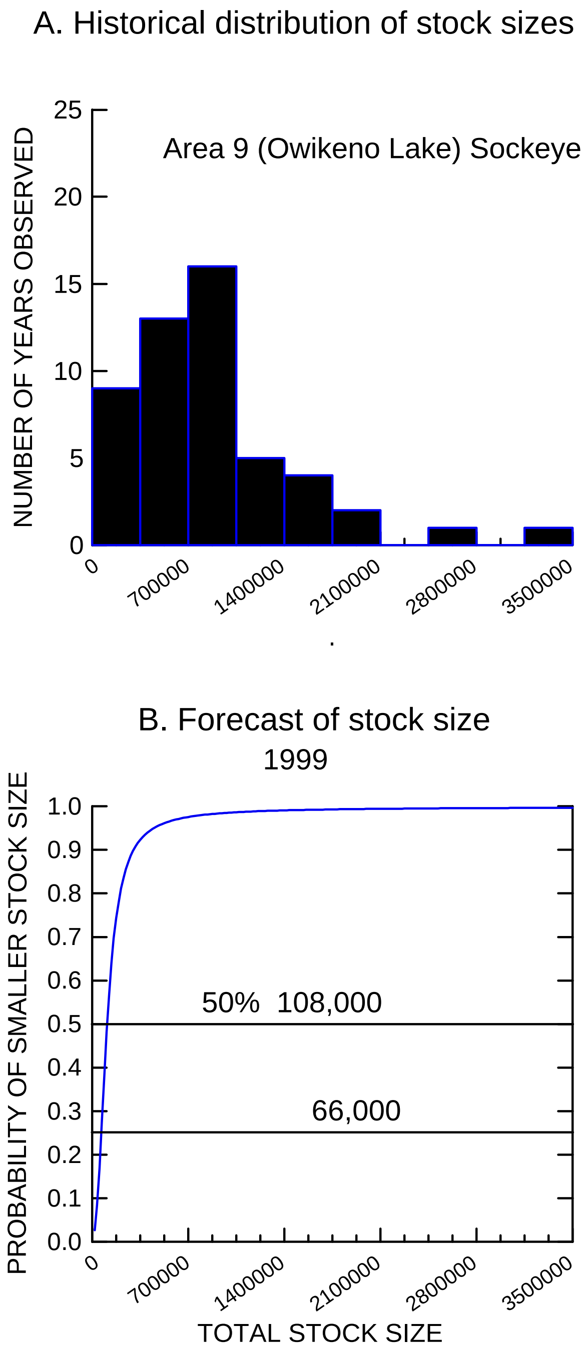


Figure 5H. The forecasted cumulative probability distribution for total stock size in 1999 for **Owikeno Lake sockeye** salmon as compared with the historical distribution of total stock size.

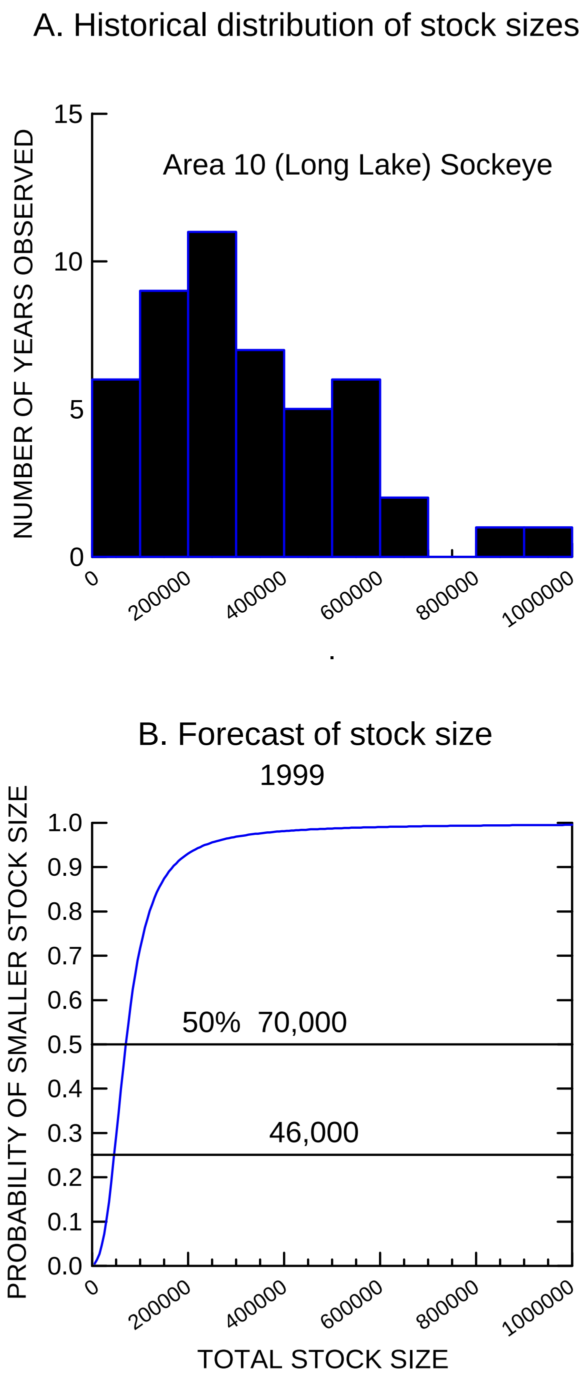


Figure 5I. The forecasted cumulative probability distribution for total stock size in 1999 for **Long Lake sockeye** salmon as compared with the historical distribution of total stock size.

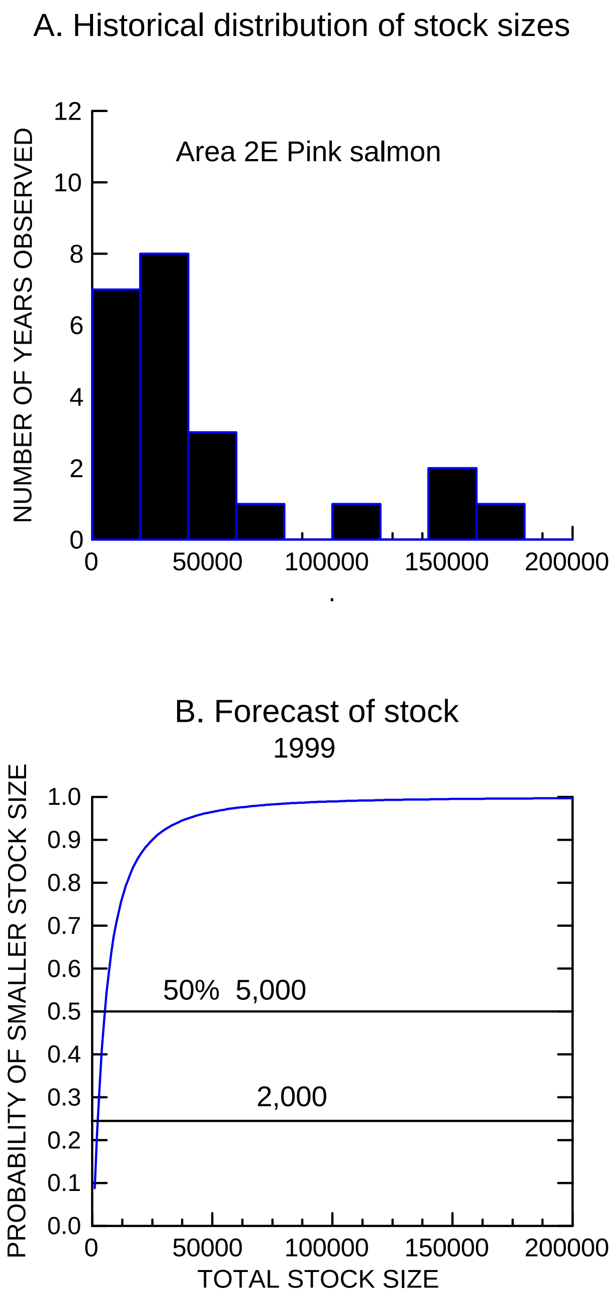


Figure 6A. The forecasted cumulative probability distribution for total stock size in 1999 for **Area 2E pink salmon** as compared with the historical distribution of total stock size for odd years.

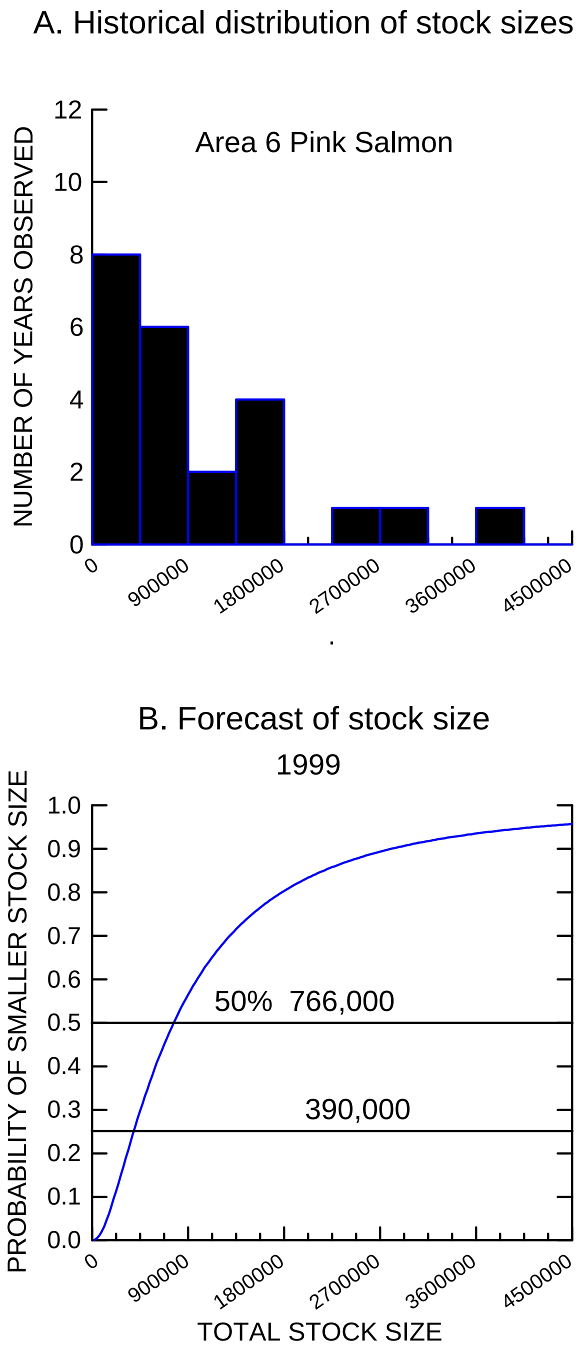
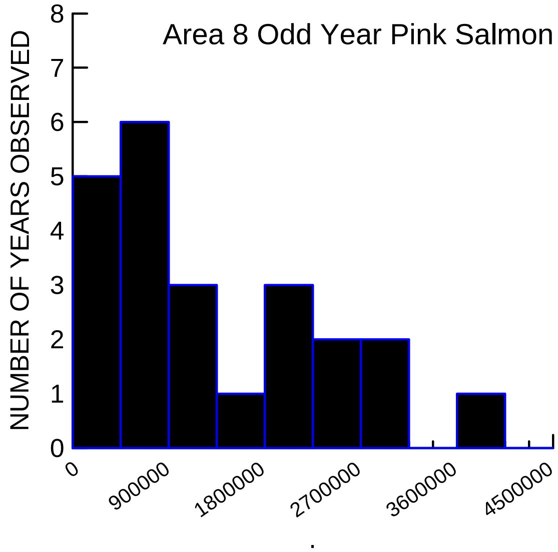


Figure 6B. The forecasted cumulative probability distribution for total stock size in 1999 for **Area 6 pink salmon** as compared with the historical distribution of total stock size for odd years.

A. Historical distribution of stock sizes



B. Forecast of stock size

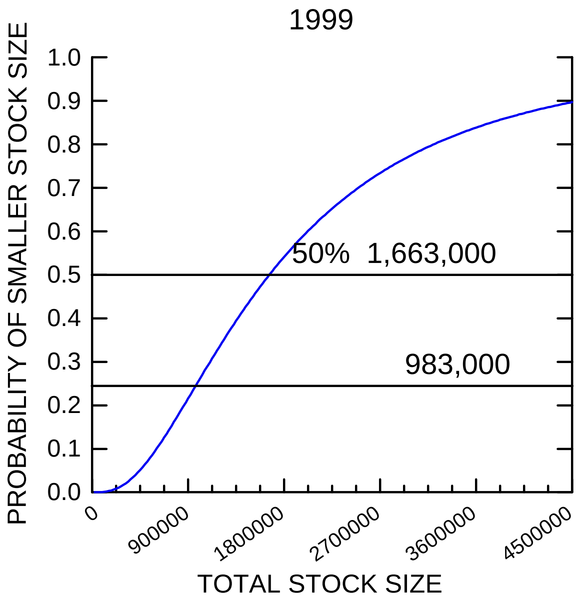


Figure 6C. The forecasted cumulative probability distribution for total stock size in 1999 for **Area 8 pink salmon** as compared with the historical distribution of total stock size for odd years.

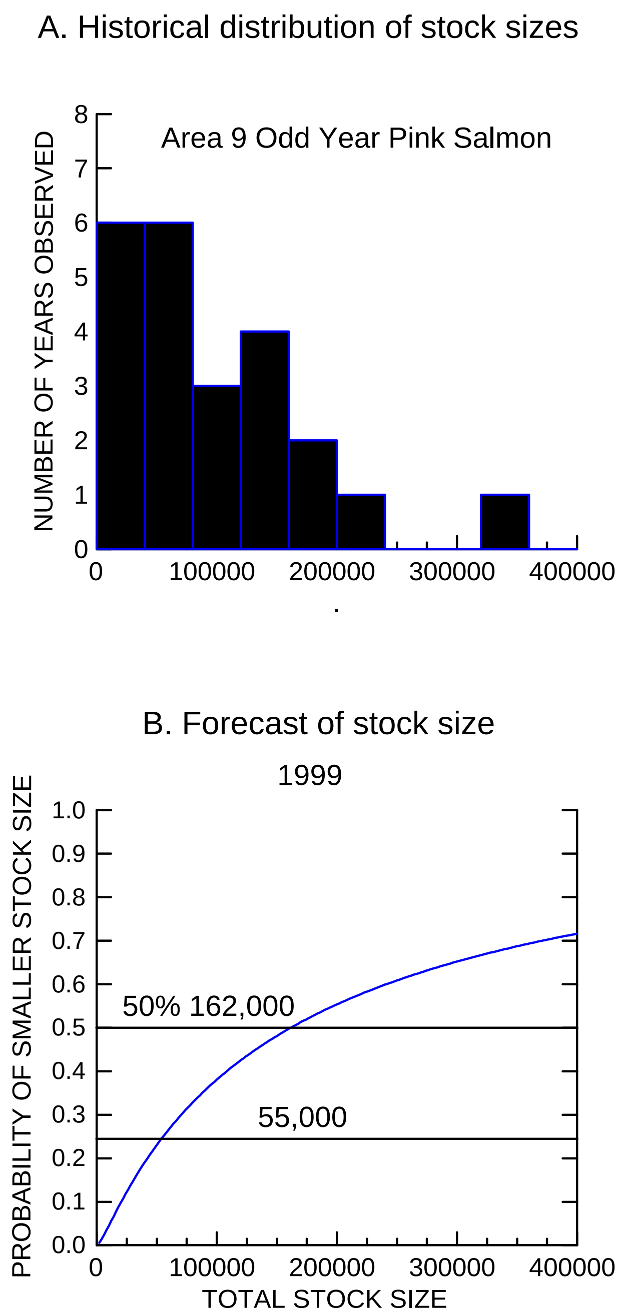


Figure 6D. The forecasted cumulative probability distribution for total stock size in 1999 for **Area 9 pink salmon** as compared with the historical distribution of total stock size for odd years.

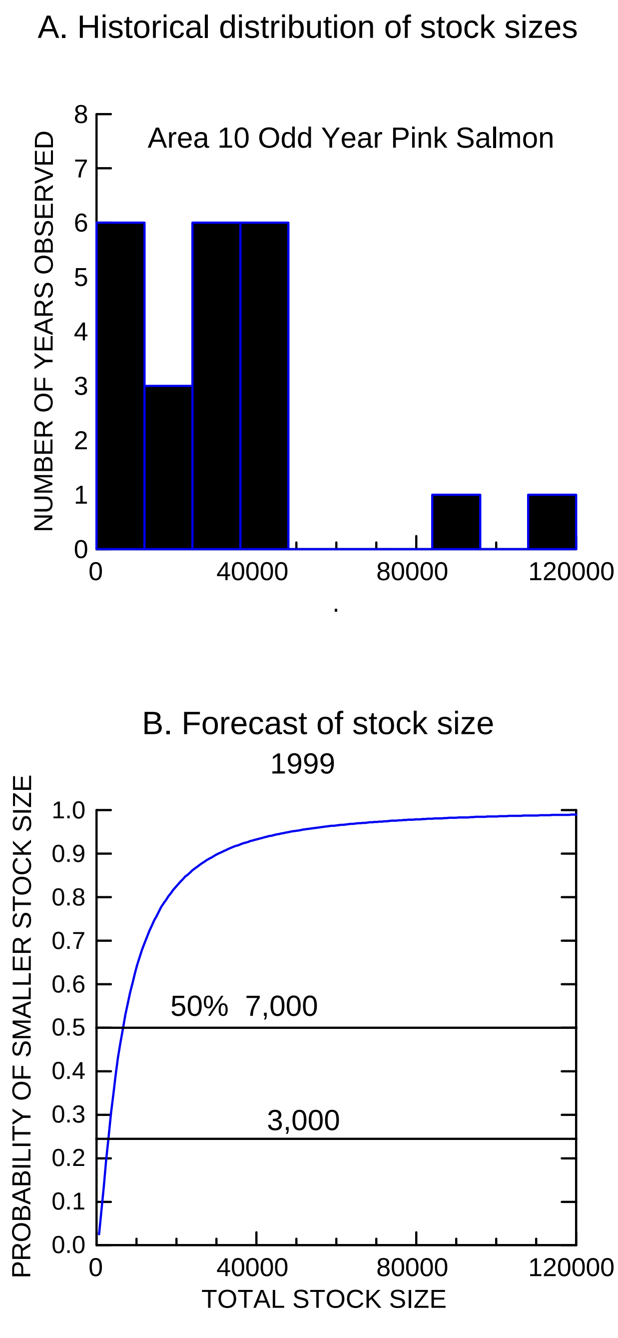


Figure 6E. The forecasted cumulative probability distribution for total stock size in 1999 for **Area 10 pink salmon** as compared with the historical distribution of total stock size for odd years.

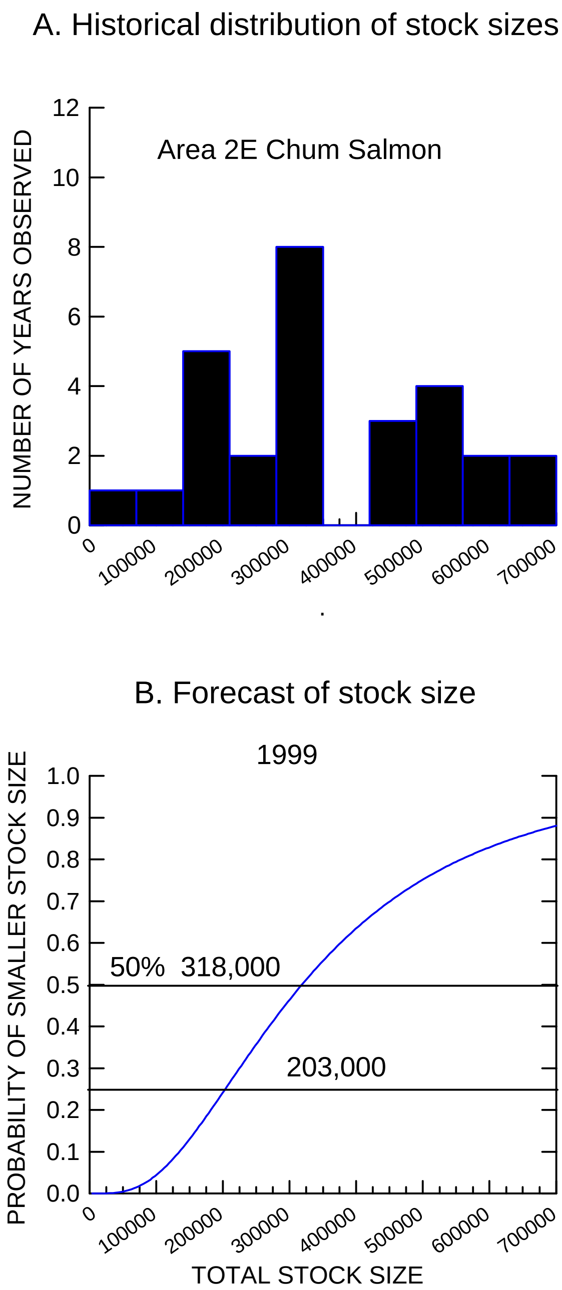


Figure 7A. The forecasted cumulative probability distribution for total stock size in 1999 for **Area 2E chum salmon** as compared with the historical distribution of total stock size.

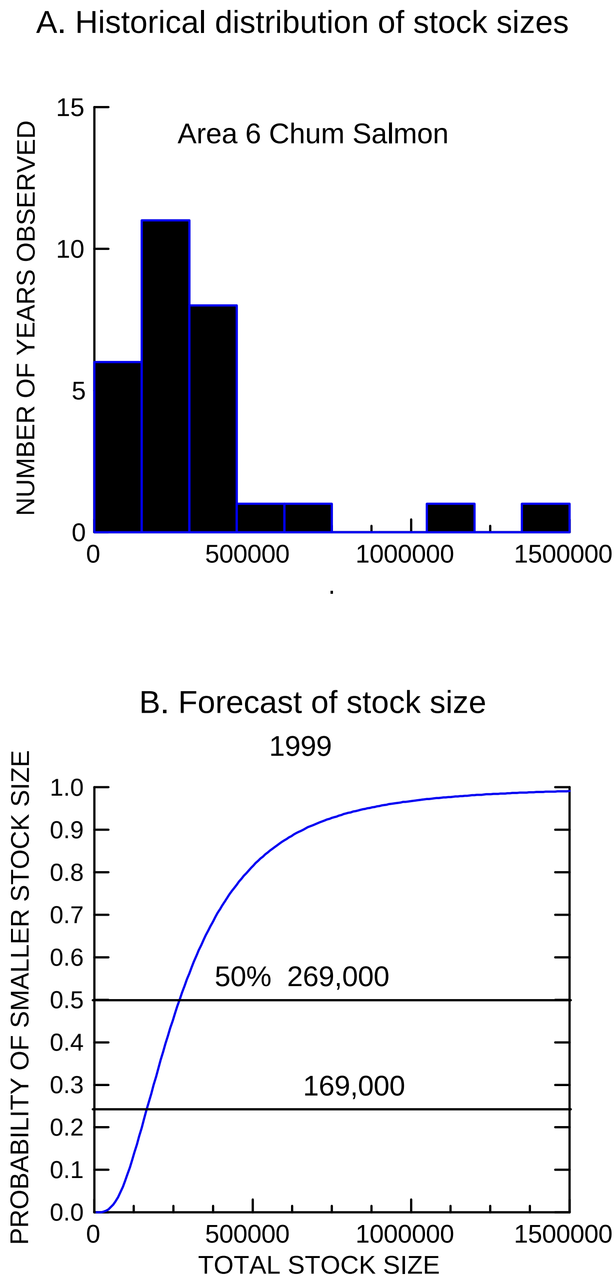


Figure 7B. The forecasted cumulative probability distribution for total stock size in 1999 for **Area 6 chum salmon** as compared with the historical distribution of total stock size.

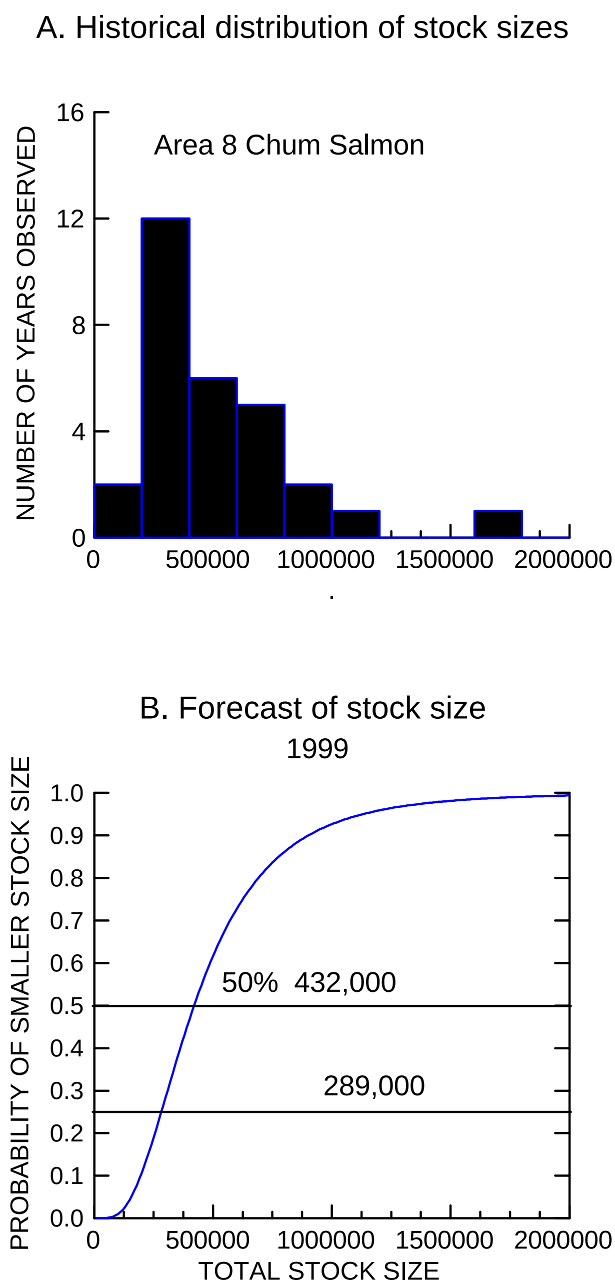
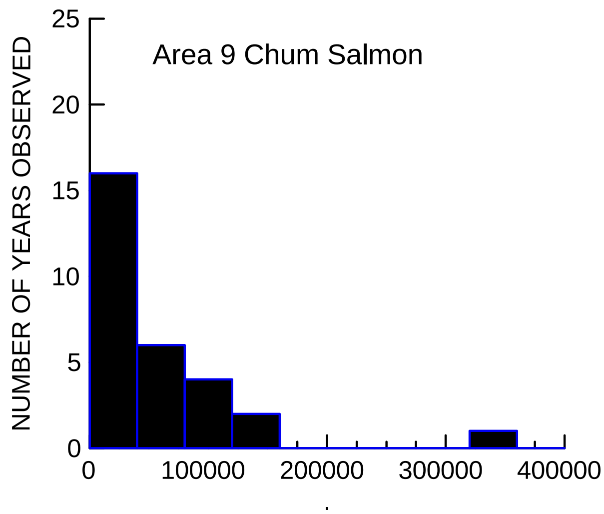


Figure 7C. The forecasted cumulative probability distribution for total stock size in 1999 for **Area 8 chum salmon** as compared with the historical distribution of total stock size.

A. Historical distribution of stock sizes



B. Forecast of stock size
1999

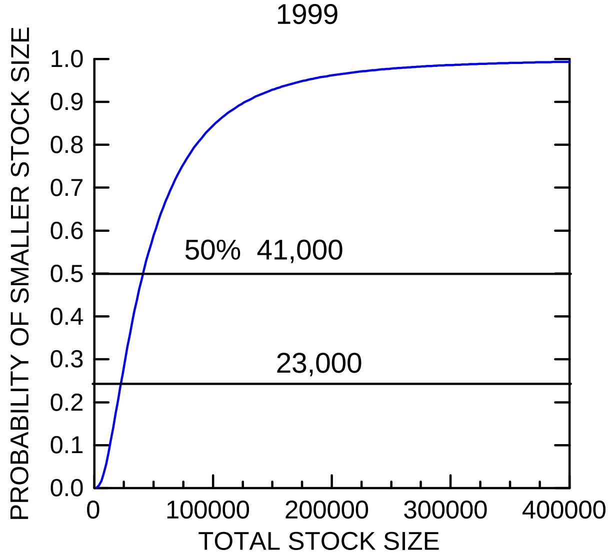
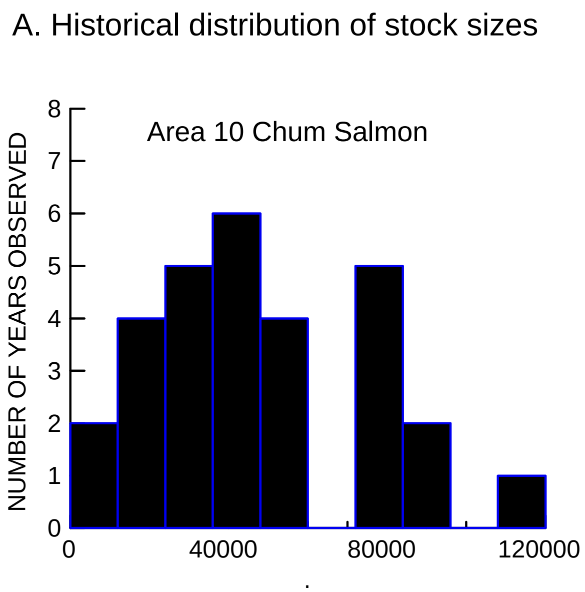


Figure 7D. The forecasted cumulative probability distribution for total stock size in 1999 for **Area 9 chum salmon** as compared with the historical distribution of total stock size.



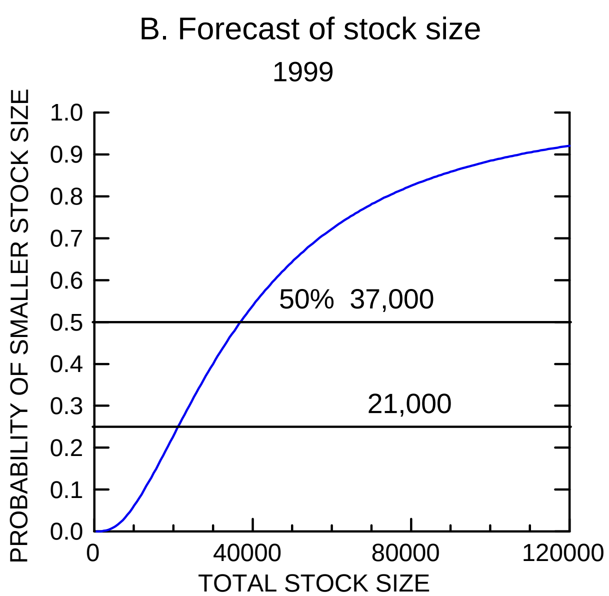


Figure 7E. The forecasted cumulative probability distribution for total stock size in 1999 for **Area 10 chum salmon** as compared with the historical distribution of total stock size.

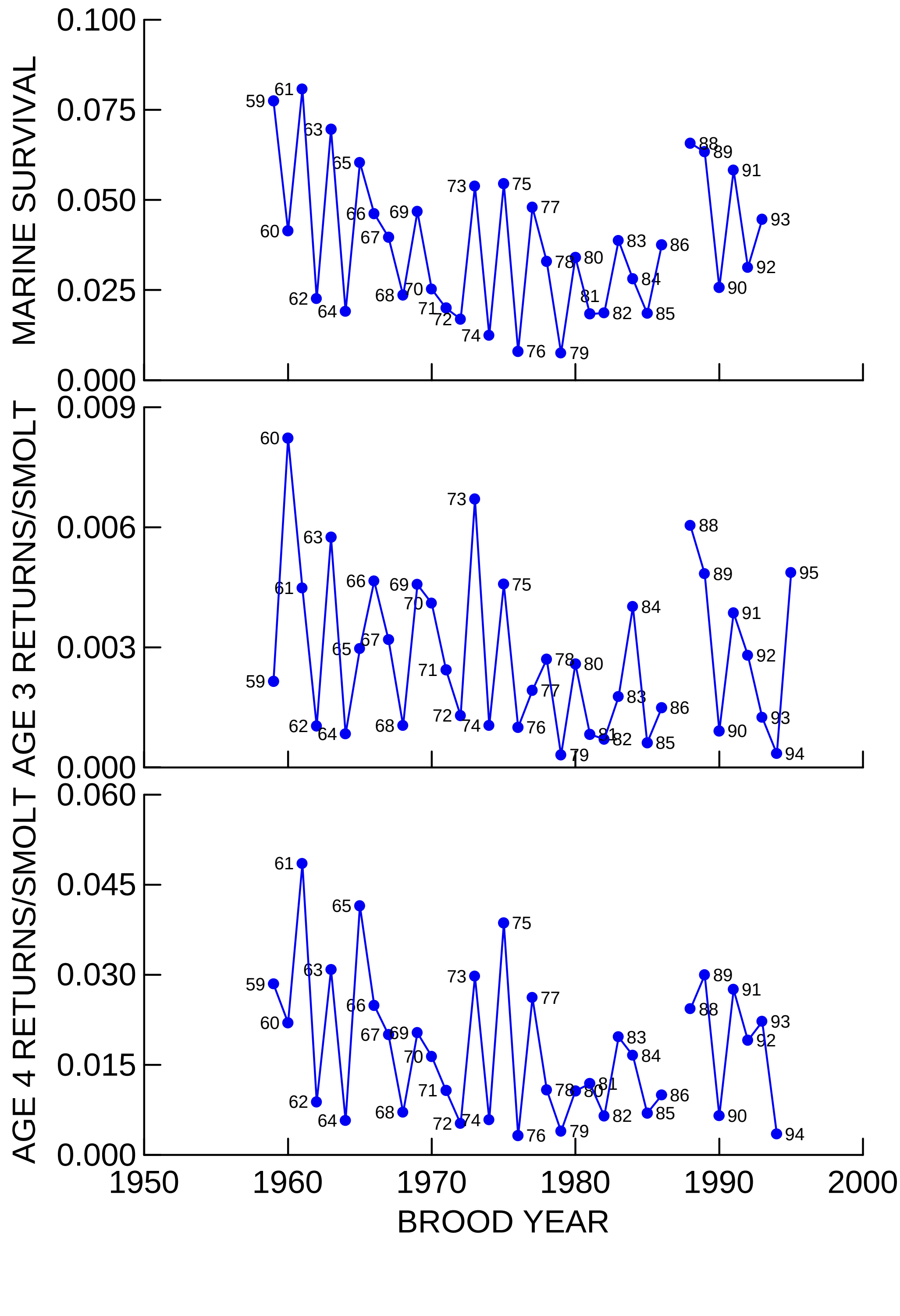


Figure 8. Trends in marine survival and smolt-to-adult return rates by age class in Skeena sockeye salmon.

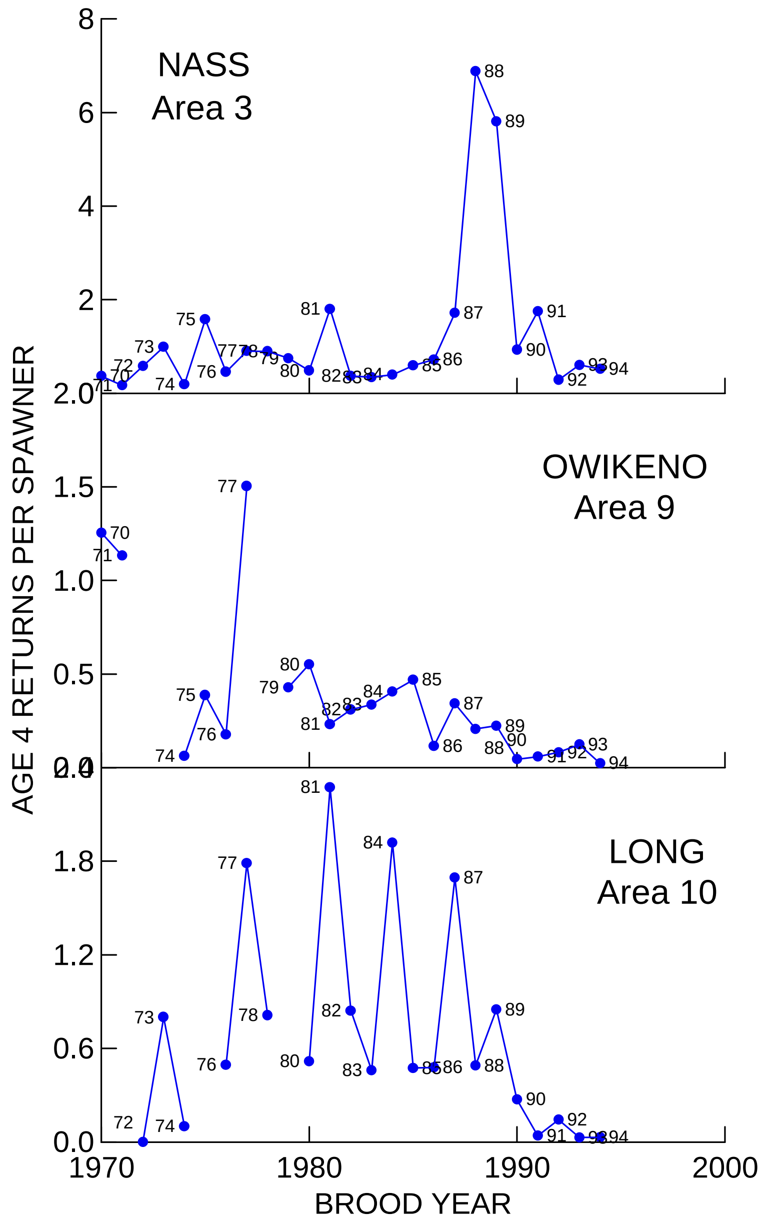


Figure 9. Trends in return rates at age 4 in Nass, Owikeno and Long Lake sockeye salmon. Note that this index provides only an approximate measure of brood year productivity in these populations where age 5 sockeye typically account for more than half of total returns.

Appendix 1. Total stock size (by calendar year) for major sockeye salmon stocks in northern British Columbia (statistical areas 1-10). These data were used to generate 1999 forecasts.

Year	Area 1 Yakoun	Area2 Skidegate	Area 3 Nass	Area 4 Skeena	Area 6 Kitlope	Area 8 Atnarko	Area 8 Kimsquit	Area 9 Owikeno	Area 10 Long
1948	.	.	.	.	.	.	.	557000	.
1949	.	.	.	.	.	.	.	840000	.
1950	.	.	.	.	.	.	.	1994000	.
1951	.	.	.	.	.	.	.	1320995	.
1952	.	.	.	.	.	.	.	1521222	.
1953	.	.	.	.	46875	118182	15000	1962285	.
1954	.	.	.	.	109375	96364	24000	679464	.
1955	.	.	.	.	10938	136364	10000	717145	.
1956	.	.	.	.	10938	136364	15000	1295832	.
1957	.	.	.	.	23438	272727	15000	586876	.
1958	.	.	.	.	46875	27273	.	1314295	.
1959	.	.	.	.	10938	136364	7000	819919	.
1960	.	.	.	.	46875	63636	15000	645303	.
1961	.	.	.	.	109375	63636	.	1004803	.
1962	.	.	.	.	234375	136364	7000	1449417	.
1963	.	.	.	.	546875	100000	.	1369959	.
1964	.	.	.	.	109375	56364	.	1627491	.
1965	.	.	.	.	46875	23636	.	785124	.
1966	.	.	.	.	62500	29091	.	728212	.
1967	.	.	.	.	109375	65455	30000	1538088	.
1968	.	.	.	.	109375	14545	7000	3282552	.
1969	.	.	.	.	10938	72727	7000	953330	.
1970	.	.	255242	1486243	46875	45455	7000	121269	.
1971	.	.	414691	1983222	46875	181818	110000	618438	.
1972	.	.	396279	1735617	10938	59091	27000	603006	135645
1973	.	.	846455	2448390	62500	154545	7000	2745156	464372
1974	.	.	567323	2552057	62500	100000	10000	675599	438718
1975	.	.	180975	1518749	31250	81818	70000	520633	115640
1976	.	.	391005	1504761	12500	54545	50000	913067	153120
1977	.	.	943012	2496644	46875	54545	20000	852419	183456
1978	.	.	485736	1184299	15625	36364	24000	960908	317486
1979	.	.	435966	2924595	15625	32727	16000	325853	31279
1980	.	.	358734	1473109	37500	43636	15000	313528	131784
1981	.	.	605623	3679645	31250	72727	10000	851781	368700
1982	.	.	858970	3785048	62500	36364	24000	862180	506632
1983	.	9990	522613	2149794	46875	45455	60000	671663	330865
1984	.	20095	421759	2392288	28125	81818	20000	268180	110172
1985	.	29121	734846	5132530	53125	90909	30000	684973	619178
1986	.	.	555858	1785674	62500	36318	32000	1163069	568854
1987	.	17862	428567	2329397	78125	55964	44000	920554	394926
1988	.	25190	308661	3855686	25000	54545	20000	875018	508731
1989	.	14427	475580	2609613	50000	27273	24400	438921	238631
1990	.	10814	375698	2628803	25000	36364	14800	820781	207579
1991	.	17455	908239	3668724	62500	95455	54000	514726	834550
1992	4968	22720	1797213	4423945	62500	74545	26000	851073	942816
1993	4155	11994	1653306	4894865	25000	27273	26000	393529	504156
1994	13216	3689	578233	2719696	48438	45455	n/i[a]	131639	157830
1995	4772	12108	933581	4763587	26250	100000	n/i[a]	118426	72188
1996	11459	19174	1045109	6865841	53125	81818	40000	65000	62513
1997	10494	10218	827716	3556646	46875	36364	10000	275000	32000
1998	7175	14642	569000	1039753	43750	54545	n/i[a]	52000	76000

[a] not inspected

Appendix 2. Escapements and total returns by brood year for major pink salmon stocks in northern British Columbia.

Odd Brood Years	Area 2E Esc	Area 2E Returns	Area 6 Esc	Area 6 Returns	Area 8 Esc	Area 8 Returns	Area 9 Esc	Area 9 Returns	Area 10 Esc	Area 10 Returns
1951	29775	26320	633825	268624	988170	945174	116025	151714	3500	30507
1953	25775	52914	121085	525712	428149	527098	44000	112781	15025	45401
1955	23275	173854	151325	237338	350294	919621	9300	57704	22500	19367
1957	46275	147003	62025	378121	571783	957270	7600	56435	7500	23176
1959	142275	58577	241975	1712843	530050	2982897	19250	149091	15025	46655
1961	42325	115404	670475	2834382	1249004	2767395	22450	52111	7500	11105
1963	115400	45916	1329750	1738302	748425	801298	16775	48717	7500	35067
1965	45700	75310	509150	196107	222100	86327	18875	30773	7500	113660
1967	71950	146157	95525	139840	66310	77984	100	23618	3500	6044
1969	120425	27440	105415	606805	59925	292963	525	58840	400	7315
1971	26700	34616	366450	633713	257150	223655	34205	99605	4000	11423
1973	34225	26029	233040	348925	166875	240528	9765	114207	5030	4062
1975	20365	11514	309079	546787	150100	529519	87150	237780	1300	38128
1977	8580	21788	142690	1214701	434690	1805033	47600	73012	20100	36953
1979	21788	9430	489720	1627895	1123325	2345963	49350	196893	30250	88264
1981	9246	13244	377395	4045529	737360	2206176	93050	136113	65037	47849
1983	13244	29366	476792	2552286	1420270	4009013	124275	352638	45271	42418
1985	19985	35799	1044801	1603737	2793620	780237	276700	173077	35600	29091
1987	35565	25977	673618	623256	383056	680921	65187	30260	18233	29325
1989	23264	14207	579398	1141704	522529	2513506	25624	6987	28106	25055
1991	14071	18346	611916	286001	2399345	1442572	4986	15384	15133	22128
1993	18141	3879	277786	618138	1184713	853534	13100	18631	10075	26657
1995	3844	5624	593594	433123	629099	1882730	18000	156922	26525	1500
1997	3295		298265		1454210		154800		1500	

Appendix 3. Catch, escapements, and total stock sizes by calendar year for major chum stocks.

	Area 2E			Area 6			Area 8			Area 9			Area10		
Year	Catch	Esc.	Total Stock	Catch	Esc.	Total Stock	Catch	Esc.	Total Stock	Catch	Esc.	Total Stock	Catch	Esc.	Total Stock
1970	363650	198975	562625	271918	105650	377568	356960	275400	632360	103742	38600	142342	49918	22500	72418
1971	302139	222350	524489	66559	90300	156859	60822	82875	143697	16710	11855	28565	8727	25000	33727
1972	281488	185780	467268	471859	271600	743459	233774	221375	455149	27460	27581	55041	33725	43250	76975
1973	430620	225350	655970	162619	278750	441369	251346	277775	529121	46569	24425	70994	43276	71500	114776
1974	149922	146440	296362	166520	258640	425160	198966	146800	345766	40904	62075	102979	13800	28500	42300
1975	1943	72562	74505	16751	79296	96047	134748	83575	218323	8266	16600	24866	5569	7500	13069
1976	47459	143420	190879	13286	67340	80626	334007	125000	459007	20853	6345	27198	3599	8500	12099
1977	170523	161075	331598	55327	85810	141137	79773	122950	202723	41995	9790	51785	13774	42500	56274
1978	115316	213567	328883	218343	185255	403598	139244	49135	188379	56344	60800	117144	38460	36000	74460
1979	0	43541	43541	88625	87805	176430	210658	99485	310143	9088	18550	27638	5488	13750	19238
1980	122390	165416	287806	200687	82862	283549	343122	123475	466597	9638	23675	33313	20221	57000	77221
1981	36774	164924	201698	96144	93410	189554	303752	107090	410842	7142	12650	19792	10990	65500	76490
1982	28719	202713	231432	142275	135783	278058	182418	129380	311798	11362	102180	113542	20129	70000	90129
1983	0	156082	156082	82258	44080	126338	331478	155045	486523	4630	34976	39606	3914	44000	47914
1984	280670	277596	558266	30727	119254	149981	70876	132260	203136	11403	26689	38092	3128	14200	17328
1985	646300	302505	948805	166290	238901	405191	536992	220865	757857	18055	28653	46708	20710	26000	46710
1986	217155	279928	497083	225590	264410	490000	1516253	266222	1782475	155491	201220	356711	15168	73600	88768
1987	191195	315766	506961	116374	114661	231035	521523	138170	659693	36167	87923	124090	14164	37500	51664
1988	392795	259102	651897	711050	460488	1171538	846088	201537	1047625	39786	44423	84209	7979	41000	48979
1989	133933	296627	430560	14877	272988	287865	237269	121789	359058	9343	10363	19706	6236	21000	27236
1990	297597	303826	601423	153301	196086	349387	688027	285515	973542	18495	14830	33325	2261	44350	46611
1991	265050	204360	469410	50747	105896	156643	235164	84607	319771	5920	7182	13102	18123	30500	48623
1992	132633	138668	271301	42227	152379	194606	155939	112447	268386	20458	16450	36908	17574	13750	31324
1993	114335	170494	284829	11599	119877	131476	186621	133188	319809	3455	9960	13415	12640	18600	31240
1994	128433	176768	305201	75142	249626	324768	492143	244997	738286	9899	15465	25364	19123	17800	36923
1995	23705	160361	184066	27842	351653	379495	532590	204550	737140	17803	24345	42148	6333	40730	47063
1996	122613	207949	330562	29578	148427	178005	166135	219339	385474	0	12400	12400	1181	23150	24331
1997	50406	154101	204507	12015	235056	247071	91861	196375	288236	0	6985	6985	0	4600	4600
1998	108263	216005	324268	541969	864236	1406205	623558	331335	954893	0	47450	47450	0	4515	4515

Appendix 4A. Escapement, total stock sizes, and age composition by calendar year for **Area 3 (Nass River)** sockeye salmon. Age 3 fish and First Nation catch excluded.

		Total	Age Composition		
Year	Escapement	Stock	% age 4	% age 5	% age 6
1970	113953	255242	24.0	71.1	4.9
1971	246774	414691	30.6	66.6	2.8
1972	177216	396279	19.1	64.8	16.1
1973	284082	846455	43.6	53.8	2.7
1974	193203	567323	7.3	80.2	12.5
1975	70874	180975	22.7	72.5	4.7
1976	142805	391005	25.9	70.3	3.8
1977	399821	943012	29.4	65.9	4.7
1978	147218	485736	7.4	80.6	12.0
1979	212890	435966	24.8	71.4	3.8
1980	155265	358734	17.3	77.3	5.3
1981	255643	605623	57.1	41.5	1.3
1982	306070	858970	14.9	80.8	4.3
1983	185100	522613	30.4	61.1	8.5
1984	182350	421759	17.6	73.6	8.7
1985	361208	734846	59.8	34.2	6.1
1986	187226	555858	20.1	70.1	9.8
1987	184212	428567	14.4	79.1	6.5
1988	136760	308661	22.5	70.2	7.3
1989	112607	475580	43.5	48.6	7.9
1990	155472	375698	29.1	64.7	6.2
1991	269848	908239	34.4	60.2	5.4
1992	645964	1797213	51.8	43.9	4.3
1993	440740	1653306	39.1	56.6	4.2
1994	179262	578233	25.5	67.8	6.7
1995	237991	933581	47.7	47.1	5.2
1996	219825	1045109	18.4	72.7	8.8
1997	237312	898998	29.7	61.4	8.9
1998	280000[a]	569000[a]	19.6	73.5	6.9

Notes
[a] preliminary estimates

Appendix 4B. Escapements and brood year returns by age class for **Area 3 (Nass River)** sockeye salmon. Age 3 fish and First Nation catch excluded.

Brood		Adult Returns			
Year	Escapement	Age 4	Age 5	Age 6	Total
1970	113953	41456	131281	14915	187652
1971	246774	41164	274913	44537	360614
1972	177216	101178	621575	58093	780845
1973	284082	276901	391518	16486	684905
1974	193203	36125	311404	19027	366556
1975	70874	108076	277474	8034	393583
1976	142805	62233	251519	37159	350911
1977	399821	346070	693916	44591	1084577
1978	147218	127895	319185	36794	483874
1979	212890	158837	310623	44742	514202
1980	155265	74342	250996	54518	379855
1981	255643	439109	389494	27951	856554
1982	306070	111846	339014	22587	473447
1983	185100	61602	216723	37795	316120
1984	182350	69351	231134	23394	323880
1985	361208	206651	242921	49267	498839
1986	187226	109382	546805	77646	733834
1987	184212	312167	788814	70012	1170993
1988	136760	930753	936150	38630	1905532
1989	112607	647144	392247	48467	1087858
1990	155472	147357	439593	90247	677196
1991	269848	445521	742494	91583	1279598
1992	645964	188150	476232	39000 [a]	1349346[a]
1993	440740	259901	408000 [a]		
1994	179262	108000 [a]			
1995	237991				
1996	219825				
1997	237312				
1998	280000 [a]				

Notes

[a] preliminary estimates

Appendix 5A. Escapement, total stock size and age composition data for **Area 4 (Skeena River)** sockeye salmon by calendar year. Age 3 fish excluded.

Year	Escapement	Total Stock	Age Composition % age 4	% age 5	% other
1970	678652	1486243	62.3	30.5	7.2
1971	821850	1983222	56.9	38.3	4.8
1972	697237	1735617	24.2	71.0	4.8
1973	820196	2448390	47.1	43.2	9.7
1974	723898	2552057	32.6	63.8	3.6
1975	822633	1518749	74.2	24.0	1.8
1976	575590	1504761	36.5	61.5	2.1
1977	951805	2496644	45.3	51.8	2.9
1978	424075	1184299	22.3	73.0	4.7
1979	1166236	2924595	85.4	10.7	3.9
1980	542164	1473109	19.6	74.2	6.3
1981	1424509	3679645	86.3	11.2	2.5
1982	1140737	3785048	16.4	80.3	3.3
1983	893724	2149794	35.1	61.0	3.9
1984	1055215	2392288	60.7	33.0	6.3
1985	2174806	5132530	33.8	64.7	1.5
1986	716312	1785674	34.2	62.5	3.2
1987	1324128	2329397	42.0	54.8	3.2
1988	1417543	3855686	68.1	27.8	4.1
1989	1137994	2609613	33.4	62.5	4.1
1990	989566	2628803	31.1	61.9	7.0
1991	1232568	3668724	24.2	67.6	8.2
1992	1550109	4423945	37.8	45.7	16.5
1993	1629426	4894865	32.7	59.2	8.2
1994	1026816	2719696	23.8	68.9	7.4
1995	1720292	4763587	48.0	44.1	7.9
1996	1782357	6865841	53.7	39.8	6.5
1997	985662	3556646	21.7	68.7	9.6
1998	531600	1039753	6.1	87.1	6.9

Appendix 5B. Escapements, smolt production, and brood year returns by age class for **Area 4 (Skeena River)** age 1.* sockeye salmon (in thousands of fish).

Brood Year	Escapement	Smolts[a]	Adult Returns Age 3[a]	Age 4	Age 5	Total
1970	679	50811	208	832	364	1404
1971	822	105240	257	1127	925	2309
1972	697	106201	137	549	1294	1980
1973	820	38098	255	1132	865	2252
1974	724	45618	48	264	313	625
1975	823	64724	296	2499	1093	3888
1976	583	90374	91	288	411	790
1977	952	121540	234	3177	3039	6450
1978	424	57505	155	622	1310	2087
1979	1166	192043	60	755	789	1605
1980	542	136566	353	1452	3323	5128
1981	1424	146245	121	1733	1117	2970
1982	1140	94609	67	611	1277	1955
1983	894	49837	88	978	1070	2136
1984	1055	159048	639	2627	1630	4896
1985	2175	125634	78	872	1628	2577
1986	714	82337	123	818	2480	3420
1987	1324		90	888	2020	2998
1988	1418	68835	416	1672	2895	4983
1989	1138	53385	258	1599	1874	3731
1990	989	99651	91	646	2100	2837
1991	1233	83096	321	2286	2741	5348
1992	1236	194134	543	3734	2444	202091
1993	1629	34797	43	772	905	38147
1994	1027	18091	6	63		
1995	1720	10000[b]	49			
1996	1794	135500				

Notes

[a] enumerated at the Babine counting fence

[b] rounded up from 8266703 in Wood et al. (1998) to reflect uncertainty in estimate due to flooding conditions