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EVALUATION OF THREE METHODS FOR PREDICTING THE ABUNDANCE INDEX FOR CHINOOK SALMON AVAILABLE TO THE SOUTHEAST ALASKA TROLL FISHERY
REPORT TCCHINOOK (97)-3

September, 1997

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List of Acronyms with Definitions

ADF&G	Alaska Department of Fish and Game
ASH	Average Shifted Histogram
CPUE	Catch Per Unit Effort
CTC	Chinook Technical Committee
CWT	Coded Wire Tag
Ln	Natural logarithm
LOA	Letter of Agreement
MAPE	Mean Absolute Percent Error
MPE	Mean Percent Error
NPFMC	North Pacific Fisheries Management Council
NWIFC	Northwest Indian Fisheries Commission
ORC	Oregon Coastal Fall Far North Migrating Model Stock
ODFW	Oregon Department of Fish and Wildlife
PNPTC	Point No Point Treaty Council
PSC	Pacific Salmon Commission
PST	Pacific Salmon Treaty
PTS	Power Troll Statistic
SEAK	Southeast Alaska – Cape Suckling to Dixon Entrance
SPFI	Stratified Proportional Fishery Index
TAC	Technical Advisory Committee
WCVI	West Coast of Vancouver Island
WDF	Washington Department of Fisheries
WDFW	Washington Department of Fisheries and Wildlife

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EVALUATION OF THREE METHODS FOR PREDICTING THE ABUNDANCE INDEX FOR CHINOOK SALMON AVAILABLE TO THE SOUTHEAST ALASKA TROLL FISHERY

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Executive Summary

In June 1996, the U.S. commissioners of the Pacific Salmon Commission (PSC) agreed on the elements of an abundance-based management regime for the all-gear chinook salmon fisheries in Southeast Alaska (SEAK). The U.S. letter of agreement (LOA) requested the PSC Chinook Technical Committee (CTC) to develop "a technically feasible procedure for estimating the aggregate abundance of chinook available to the SEAK fishery using inseason fishery performance data, for the purpose of adjusting preseason forecasts of harvest levels beginning in 1997" (Allen et al. 1996).

The bilateral CTC evaluated three methods for predicting the estimated abundance index of chinook available to the SEAK troll fishery. The assessments were based on data collected for the period 1979 through 1996 as well as abundance forecasts for 1997, which were either provided by agencies or represented by the PSC chinook model estimates. The years used in each assessment varied, depending on the appropriateness of the data, but each method was compared with estimated chinook abundance indices from the PSC chinook model calibration 9702 (CTC Report TCCHINOOK (97)-2). The three methods compared follow:

PSC Chinook Model Forecast. The preseason forecast of the estimated chinook abundance index for the SEAK troll fishery is based on the PSC chinook model.

Inseason Prediction. A prediction of the estimated abundance indices for year *i* is based on fishery performance data from the troll fishery in year *i* and PSC chinook model estimated abundance indices. Various measures of fishery performance were assessed before selecting the statistic used in this report (Power Troll Statistic (PTS) = power troll catch per permit making a landing during the first 5 days of the summer troll season).

Bayesian Prediction. The application of Bayesian statistics to predict the estimated chinook abundance index is introduced. This method integrates information from both of the above methods and can be used inseason. This method does not introduce any new data into the estimation, but it combines the above methods based on the reliability of their historical relationships. Further, this method incorporates explicit estimates of the uncertainty in each of the above methods used to estimate the CTC abundance index.

The ability of each method to predict the estimated abundance index from the PSC chinook model was examined through retrospective analyses. The models were assessed by leaving one year of data out from a relationship, recalculating the relationship, and then predicting the value for the year omitted. This process, called hindcasting (PSC model) or jackknifing (inseason and Bayesian models), allows comparison of several predictions per model by comparing each prediction with the value actually observed, but omitted. The criteria for comparison between models were the mean percent error (MPE, the expected average error over time, a measure of bias), the mean absolute percent error (MAPE, the average annual error, a measure of uncertainty), and the maximum positive and negative errors (also measures of uncertainty and range of values).

The PTS and Bayesian predictions exhibited smaller MAPE, and lesser ranges of maximum errors than the model forecast abundance index. The Bayesian model exhibited the smallest MPE and the smallest maximum positive deviation. Consequently, the Bayesian method is the preferred method for predicting the estimated abundance index for the SEAK troll fishery.

Comparison of errors and range of errors by method determined from hindcasting for the 1987-1996 period (see text Table 12).

	CTC Model Forecast	Inseason Prediction	Bayesian Prediction
MPE	+3%	+3%	+1%
MAPE	10%	8%	8%
MAX +	+25%	+22%	+15%
MAX -	-15%	-8%	-13%

The Bayesian method generates a distribution of abundance index values, given the PTS value observed in the current fishery and the CTC forecast abundance index. ***The CTC recommends that the mode of this Bayesian posterior distribution be used as the "most probable" value of the estimated abundance of chinook salmon in the SEAK troll fishery.*** The CTC also notes that the uncertainty about the predicted abundance index is also estimated. ***The CTC recommends that the PSC consider how the new information on uncertainty could also be usefully employed in management.***

The CTC also notes that the current analysis of probability distributions relies upon limited data sets: 10 years for the hindcasted PSC model forecasts and 17 years for the PTS. However, future improvements in the PSC model forecasts are likely, and improved measures of inseason fishery performance may be identified. There are also concerns about the time trends in the error about the preseason forecast of the abundance index. ***The CTC recommends reevaluation of procedures to estimate abundance of chinook available to the SEAK fishery using inseason information prior to the 1999 fishing season.***

This report is limited to the technical development of an inseason procedure that incorporates the PTS and provides an estimated abundance index for chinook available to the all-gear SEAK fishery. The CTC did not evaluate the extent to which variations in stock distributions influence the abundance index for the SEAK chinook fishery. Concerns of some CTC members with issues that may arise when integrating inseason adjustments to abundance for the SEAK fishery with regimes for other fisheries to achieve management objectives for harvest sharing and stock rebuilding are not addressed, because these considerations are beyond the scope of this technical assignment.

The Canadian CTC members wish to clarify that their review of the techniques in this report does not imply endorsement of any aspect of the U.S. LOA or the application of this technique to one fishery in isolation of others.

1.0 INTRODUCTION

In June 1996, the U.S. commissioners of the Pacific Salmon Commission (PSC) agreed on the elements of an abundance-based management regime for the all-gear chinook fisheries in Southeast Alaska (SEAK). Under this regime target catches and harvest rate indices, as estimated by the stratified proportional fisheries index (SPFI), are dependent upon the forecast abundance index developed by the Analytic Work Group (1989) of chinook[1] available to the SEAK troll fishery (Figure 1). To implement the regime, the PSC Chinook Technical Committee (CTC) provides an abundance forecast in order to establish a target catch number for the SEAK all-gear chinook fishery. Further, for the purpose of adjusting preseason forecasts of harvest levels beginning in 1997, the U.S. Letter of Agreement (LOA) requested the CTC to develop a technically feasible procedure for estimating the aggregate abundance of chinook available to the SEAK fishery using inseason fishery performance data (Allen et al. 1996).

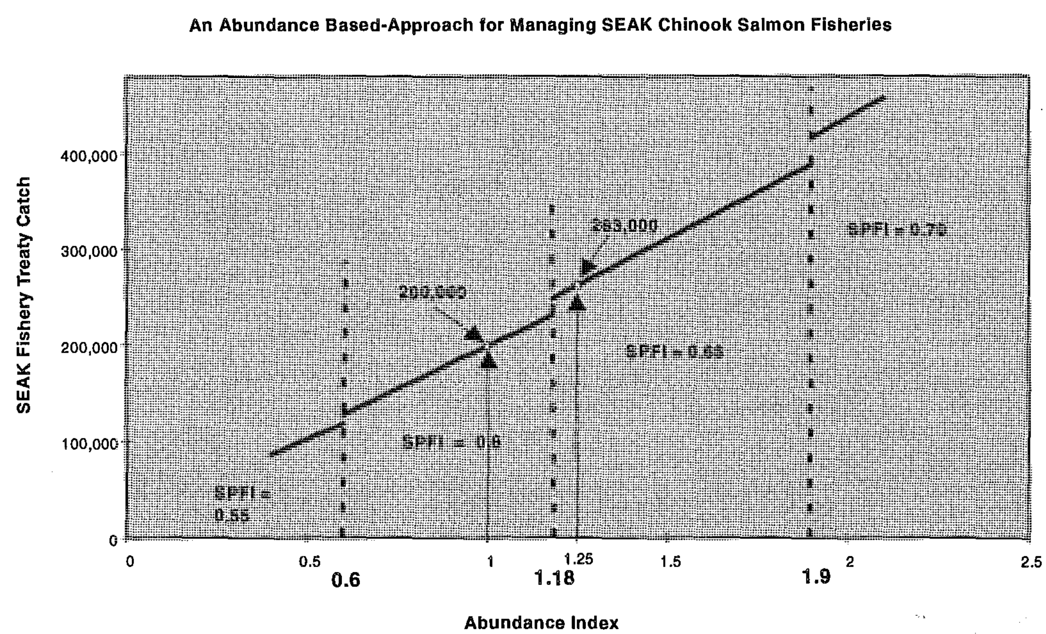

Figure 1. The abundance-based approach to management of the all-gear SEAK chinook fishery described in the 1996 U.S. Letter of Agreement (Allen et al. 1996).

1 All abundance estimates in this report refer to "treaty chinook" or chinook salmon not originating from SEAK hatcheries. The U.S. LOA also prescribes how additional catch of chinook salmon originating from SEAK hatcheries can be added to the target catch at each abundance level.

This report evaluates three methods for predicting the abundance index of chinook available to the SEAK troll fishery. The performance of each method was evaluated on a post-hoc basis for the years 1987 through 1996:

PSC Chinook Model Forecast. For each year, a forecast abundance index for the SEAK troll fishery is obtained by calibrating the CTC chinook model using agency and model-generated forecasts of chinook abundance for each model stock.

Inseason Prediction. The inseason model uses the historical relationship between fishery performance and the CTC index of chinook abundance to predict the abundance index for chinook available to the SEAK troll fishery.

Bayesian Prediction. The Bayesian model does not use any new data, but combines the information from the chinook model and the inseason model to predict the abundance index for chinook available to the SEAK troll fishery.

This report is limited to the technical development of an inseason abundance index for chinook available to the SEAK troll fishery. The CTC did not evaluate the extent to which variations in stock distribution influence the abundance index for the SEAK troll fishery. Concerns of some CTC members with issues that may arise when integrating inseason adjustments to abundance for the SEAK troll fishery with regimes for other fisheries to achieve management objectives for harvest sharing and stock rebuilding are not addressed, because these considerations are beyond the scope of this assignment.

2.0 DEFINITIONS

Key terms used throughout this report are defined below:

Agency forecast: A forecast of abundance (typically, terminal run or expected escapement in the next year) for a particular stock provided by the relevant management agency.

Bayes methodology: A procedure for describing uncertainty in unknown parameters and variables given (i) assumptions about the error structure in prior information and (ii) the observed current data. Bayes' theorem provides a formal rule for sequentially updating prior views of this uncertainty for data later observed. This uncertainty is quantified as a probability density from which probabilities for ranges of unknown parameters or variables can be computed: the density preceding new data is called a prior density, and the revision is called a posterior density.

Fishery abundance index: A measure of the number of chinook that are larger than the minimum size limit and available to a fishery, relative to the 1979 through 1982 base period average, assuming a geographic distribution generated by the CTC model is identical to the base period.

Estimated (postseason) abundance index: A postseason estimate of the fishery abundance index calculated by the PSC chinook model. Using the best available data and accounting for past management actions, new estimates are made for each fishery and year after each calibration of the model.

Forecast abundance index: A preseason estimate of the fishery abundance index calculated by the PSC chinook model. The estimate is based on agency preseason forecasts for some stocks and model projections for stocks without agency forecasts (Appendix A).

Hindcasting: The jackknifing in this report was completed by removing from the current data set the data collected in the year for the prediction. For example, if data from 1983 through 1996 were used in a regression model to forecast stock abundance, abundance index for the year 1987 would be estimated by using the parameters of the regression model with the 1987 data omitted.

Inseason abundance index: An inseason estimate of the estimated postseason abundance index derived from fishery performance data.

Jackknifing: A 'leaving-out' procedure for evaluating the performance of a model on a post-hoc basis.

Power troll statistic: The total catch (excluding chinook originating from SEAK hatcheries) by power troll gear during the first 5 days of the summer season divided by the number of power troll permits with landings during that period.

3.0 NATURE AND CONDUCT OF THE SEAK TROLL FISHERY

Two types of gear, hand troll and power troll, are used in the SEAK troll fishery. Vessels using hand troll gear are typically 14 to 28 ft. in length and are limited to two lines on hand-operated gurdies or four sport fishing poles. Vessels using power troll gear are generally larger than hand troll vessels and limited to four lines on power-operated gurdies, except within the Exclusive Economic Zone (EEZ) north of the latitude of Cape Spencer, where six lines may be used.

Beginning in 1975, the number of power troll permits was fixed at 950. In 1979, the beginning of the base period for the abundance index, the number of permits fished was 813. Between 1979 and 1995, the number of permits fished annually ranged from 797 in 1981 to 855 in 1991. In 1996, the total number of troll permits fished was 737, the lowest since entry into the fishery was limited.

Entry into the hand troll fishery was limited in 1980, and the total number of permits was fixed at 2,150; however, only 804 of these permits can be traded. The rest will not be renewed when the designee no longer fishes.

Prior to 1980, the troll fishery operated throughout the year. There were two general seasons: winter and summer. The winter fishery occurred primarily in inside waters from October 1 through April 14. Beginning in 1980, the commercial troll and net fisheries were managed for a guideline harvest level established by the North Pacific Fishery Management Council (NPFMC), resulting in the closure of the summer troll fishery for a total of 20 days. Beginning in 1981, in addition to managing for the guideline harvest level, the fishery was closed from April 15 through May 14 to protect spring stocks in the SEAK region.

With enactment of the PST and a coastwide program to rebuild depressed naturally spawning chinook stocks in 1985, a ceiling of 263,000 'treaty chinook' was set for the SEAK all-gear fishery. The number of chinook available for the SEAK troll fishery is determined, in part, by allocation decisions of the Alaska Board of Fisheries. Since 1988, the general summer fishery has opened on July 1 (Appendix B, Table B-1). In 1992, the winter fishery was delayed by 10 days, opening on October 11.

At present, the accounting year for chinook begins with the opening of the winter troll fishery on October 11 and ends on September 30 of the next year. The winter fishery continues through April 14 or until a total of 45,000 chinook has been harvested. Between April 15 and June 30, spring troll fisheries are conducted to target on mature Alaska hatchery chinook. Beginning July 1, the general summer troll fishery begins with a target catch of 70% of the remaining allowable troll harvest of treaty chinook. The remainder of the fish are taken in open periods following any closures of the coho salmon fishery. When the coho fishery is reopened, captured chinook are retained until the final quota is met. When the quota has been met, captured chinook are no longer retained and areas where chinook are abundant are closed to fishing, thereby reducing the mortality associated with capture and release.

Estimated Effort. In six SEAK areas (Figure 2), total effort in boat days was estimated for power trollers in the general summer commercial troll fishery during periods of chinook retention from 1981 through 1996 (Carlile and Gaudet 1996). The estimates of boat effort do not include effort in the hatchery-access, experimental, or terminal fisheries. Although the number of power troll boat days for chinook has dropped from 62,225 in 1981 to 2,445 in 1992 (Table 1), there does not appear to be a change in the distribution of effort throughout the region (Table 2).

Technological Changes. Several major technological improvements in trolling have occurred. The marine radio and depthsounder were introduced into regular use in the 1950s and 1960s. Later, the use of LORAN and GPS allowed trollers to more easily locate favorite fishing locations. Finally, during the 1980s, some boats began using plotters which allowed them to return to certain drags. At present there is no discrete measurement of a change in vessel efficiency over time.

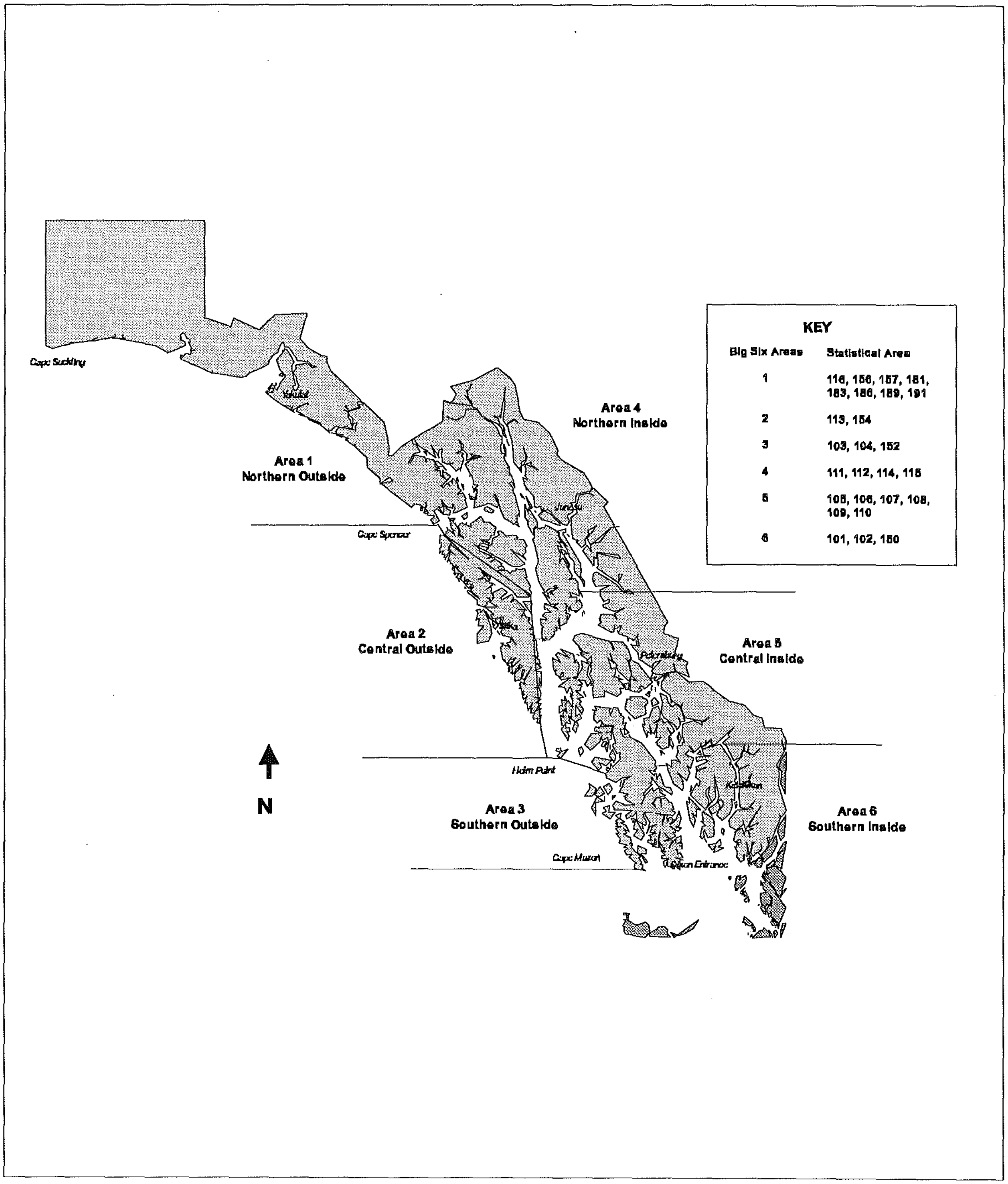

Figure 2. Data collection areas for the southeast Alaska troll fishery.

Table 1. The estimated number of boat days by power trollers during periods of chinook retention during the general summer troll fishery, 1981 through 1996.

	Outside			Inside			
Year	Northern	Central	Southern	Northern	Central	Southern	Total
1981	6,222	29,642	11,305	6,173	6,071	2,812	62,225
1982	2,893	22,951	8,903	3,546	3,366	2,221	43,880
1983	3,048	20,620	5,810	3,604	5,278	2,549	40,910
1984	1,527	15,901	3,994	2,251	3,127	1,387	28,188
1985	3,558	13,776	3,954	2,011	2,193	838	26,331
1986	3,042	12,833	2,577	1,010	2,585	839	22,886
1987	727	9,677	2,800	491	2,422	346	16,462
1988	440	4,657	1,442	373	793	112	7,816
1989	1,246	4,075	957	466	1,142	254	8,140
1990	2,613	6,996	2,643	656	1,119	671	14,698
1991	376	2,165	625	55	436	161	3,817
1992	97	1,349	502	152	191	154	2,445
1993	201	3,655	1,333	633	758	218	6,798
1994	632	2,710	1,084	707	522	121	5,776
1995	615	3,710	1,348	626	548	85	6,931
1996	372	2,389	930	468	347	75	4,582

Table 2. The distribution by year, mean and standard deviation of power troll effort in the six areas of SEAK, 1981 through 1996.

	Outside			Inside		
Year	Northern	Central	Southern	Northern	Central	Southern
1981	10%	48%	18%	10%	10%	5%
1982	7%	52%	20%	8%	8%	5%
1983	7%	50%	14%	9%	13%	6%
1984	5%	56%	14%	8%	11%	5%
1985	14%	52%	15%	8%	8%	3%
1986	13%	56%	11%	4%	11%	4%
1987	4%	59%	17%	3%	15%	2%
1988	6%	60%	18%	5%	10%	1%
1989	15%	50%	12%	6%	14%	3%
1990	18%	48%	18%	4%	8%	5%
1991	10%	57%	16%	1%	11%	4%
1992	4%	55%	21%	6%	8%	6%
1993	3%	54%	20%	9%	11%	3%
1994	11%	47%	19%	12%	9%	2%
1995	9%	54%	19%	9%	8%	1%
1996	8%	52%	20%	10%	8%	2%
Average	9%	53%	17%	7%	10%	4%
Standard Deviation	4%	4%	3%	3%	2%	2%

4.0 METHODS

The performance of three methods for predicting the estimated abundance index for the SEAK troll fishery were evaluated in this analysis: (1) the PSC chinook model forecast abundance index, (2) the inseason abundance index estimated from fishery performance data, and (3) a Bayesian estimate of the inseason abundance index using the forecast abundance index and fishery performance data. The performances of each of the predictors was evaluated using hindcasting and jackknifing for the years 1987 through 1996. Years prior to 1987 were not included in the analysis because forecasts of abundance for the West Coast of Vancouver Island (WCVI) stocks were not possible. Details of the analysis for each prediction method are provided in the following sections. All three of the methods are evaluated by comparisons with estimated abundance indices for past years obtained from the PSC chinook model (Calibration 9702; CTC 1997).

Model-based indices use a variety of data, including biological information (e.g., productivity, escapement goals, age at maturity, catch distribution patterns, survival rates, enhancement levels) for representative stocks, estimates of fishing mortalities, and observed and projected management actions. During the model calibration process, parameters of the model are estimated using new information on the conduct of fisheries (e.g., catch levels, chinook nonretention), escapement estimates, and abundance projections. The calibration estimates brood year survival rates for each of the 30 stocks represented in the model. To estimate the total abundance of all model stocks available to a fishery, survival numbers are then combined with base period stock-fishery exploitation rates, production estimates for wild and hatchery stocks, and regulatory measures (e.g., size limits). An index of abundance is computed by dividing the estimated abundance in any year by the average abundance during the base period (1979 through 1982).

The abundance (K_f) during the base period (1979 through1982) was computed as:

$$K_f = \frac{\sum_{i=1979}^{1982} \sum_{s=1}^{S} \sum_{a=2}^{A} C_{s,a,i} \times v_{s,a,f} \times (1 - PNV_{a,f})}{4} \quad 1$$

where:

- s : stock (1...,S)
- f : fishery (1...,F)
- a : age (2...,A)
- i : year (1...,Y)
- $v_{s,a,f}$: base period exploitation rate on the vulnerable cohort;
- $C_{s,a,i}$: cohort size after natural mortality
- $PNV_{a,f}$: proportion nonvulnerable, i.e., age-specific estimates of the proportion of fish not vulnerable to the fishing gear or smaller in length than the minimum size limit currently in effect.

A fishery abundance index (τ_i) was then computed by dividing the fishery abundance in any year by the base period average abundance:

$$\tau_i = \frac{\sum_{s=1}^{S} \sum_{a=2}^{A} C_{s,a,i} \times v_{s,a,f} \times (1 - PNV_{a,f})}{K_f}$$

The estimated abundance indices for the years 1980 through 1996 were obtained from the most recent calibration of the model (Calibration 9702; CTC 1997).

4.1 Chinook Model Forecast

The accuracy and precision of forecast abundance indices generated with current agency forecast methodologies, were evaluated by comparing them with estimated abundance indices for the SEAK troll fishery for the years 1987 through 1996. The current model structure code was used to develop 10 hindcasted model calibrations. For example, the model forecast for 1987 was obtained from a model calibration that included observed data for years through 1986 and stock abundance forecasts for 1987. Data from more recent years would be excluded from that calibration. The methods used to compute the forecasts for each model stock are summarized below, and the forecasts are provided in Appendix A.

Improvements in data, agency forecasting methodologies, and the chinook model may have increased the accuracy and precision of the abundance projections relative to actual performance in past years. However, for comparisons of predictors and Bayesian analysis, the key question is "how well would we have predicted abundance indices in past years with current agency databases, forecast methodologies, and version of the chinook model?" The answer to this question provides the appropriate basis to evaluate forecasting error using our current information and methods. Addressing this question is different from measuring forecasting error based on historical versions of the chinook model.

4.1.1 Agency Preseason Forecasts

The CTC relies upon management agencies to provide forecasts of abundance for the stocks included in the PSC chinook model. The methods used by the agencies to develop the forecasts vary considerably, both between agencies and over time, as methods incorporate additional insight and information. Generally, among other factors, these forecasts depend upon (1) the types of data available and (2) the time the data become available.

There are roughly three types of agency forecasts of abundance:

Sibling Models. Sibling models relate a measure of abundance (commonly, terminal run size) of age ***i*** fish in year ***y*** to the abundance of the run of age ***i+1*** fish in year ***y+1***. The source of the abundance information may be either recoveries of coded wire tags (CWT) from tagged fish or an age-structured run reconstruction for the entire stock.

Average Return Rate Models. Return rate models relate terminal runs to prior production. The prior production is often the number of smolts released for hatchery stocks and the brood escapement for wild stocks.

Average Return Models. Some forecasts consist simply of the average return in recent years. These models are common where data are limited and/or stock abundance cannot be shown to be related to either prior production or returns of younger age classes in previous years.

The forecast methods used by the management agencies for each model stock are summarized in Table 3. A more detailed description of the forecast methods used in hindcasting for 1987 through 1996 follows. In some instances, data sets or forecast techniques used to predict recent-year terminal runs were not available in the early years of PSC management and preseason forecasts were not supplied; e.g., in 1994 the Oregon Department of Fish and Wildlife (ODFW) developed an age-specific terminal run predictor for the Oregon Coastal Fall Far North Migrating (ORC) model stock. In these cases, the current forecast methodology and data set (with the exception of the forecast year) were used to develop a forecast for each year with the necessary data. Agencies provide forecasts for 21 stocks in the model. In the absence of a forecast, the PSC chinook model predicts the cohort size using adult escapement, stock productivity parameters, and average stock productivity scalar of prior broods.

Oregon Coastal Fall Far North Migrating. The ORC stock is a major contributor to SEAK fisheries. The ODFW began providing age-specific forecasts to the CTC in 1994. Methods used by ODFW (Williams 1995) to forecast the 1995 terminal run were applied on a post-hoc basis to the years 1990 through 1993. Forecasts for prior years were not possible because of the lack of age-specific estimates of the terminal run.

To predict the terminal run of the ORC model stock, sibling regressions are first used to predict the age-specific return of tagged fall chinook from the Salmon River Hatchery. These predictions are then adjusted by the number of CWTs released to match the maximum release in the data set. A regression of the total adjusted return of CWT fish versus return of all ORC stocks is used to predict the total return of ORC. The age composition of the total return is assumed to be the same as the predicted age composition of the unadjusted CWT return prediction.

Columbia River Stocks. Forecasts for fall chinook stocks were obtained from Washington Department of Fisheries and Wildlife (WDFW 1989, 1997). Distinct types of forecasts are generally available at different stages of the preseason management-planning process: (a) nonage-specific forecasts (termed the general forecast) become available in December and are used to provide an early indication of abundance expectations for the coming season; (b) preliminary age-specific forecasts become available in mid-February for use in the Pacific Fishery Management Council's (PFMC) annual planning process; during this process, age-specific terminal run sizes are estimated, based on deviations in ocean fisheries from those observed historically; and

Table 3. Methods used by agencies in 1997 to forecast abundance of stocks in PSC chinook model. (Forecast Type codes: S=sibling model; R= return rate; A=average return; C=PSC Model).

Model Stock	Forecast Characteristics			Comments
	Forecast Type	Preseason Age-Specific	Postseason Age-Specific	
Alaska South SE	C	NA	No	
North/Central BC	C	NA	No	
Fraser Early	C	NA	No	
Fraser Late	S	Yes	Yes	
WCVI Hatchery and Wild	S	Yes	Yes	
Upper Strait of Georgia	C	NA	Yes	
Lower Strait of Georgia Wild	C	NA	Yes	
Lower Strait of Georgia Hatchery	C	NA	Yes	
Nooksack Fall	R	No	No	
Puget Sound Fall Fingerling and Yearling	S,R	No	No	sibling model now used for Green River; others use return rate
Puget Sound Natural Fall	R,A	No	No	average return used for a few stocks
Nooksack Spring	C	NA	No	
Skagit Summer/Fall Wild	R	Yes	Partial	
Snohomish Summer/Fall Wild	R,A	No	No	average of two methods used in '95
Stillaguamish Summer/Fall Wild	R	No	No	
Washington Coastal Fall Hatchery	C	NA	No	
Washington Coastal Fall Wild	C	NA	No	
Columbia Upriver Bright	S	Yes	Yes	
Mid-Columbia Bright Hatchery	S	Yes	Yes	
Spring Creek Hatchery	S	Yes	Yes	
Lower Bonneville and Fall Cowlitz Hatchery	S	Yes	Yes	
Lewis River Wild	S	Yes	Yes	
Cowlitz Spring	S	Yes	No	
Willamette River Spring Hatchery	S	No	Yes	
Columbia Upriver Summer	S	No	No	jack:adult regressions
Oregon Coastal Fall Far North Migrating	S	Yes	Partial	sibling relationships estimated using CWTs; expanded for untagged fish
Snake River Fall Wild	S	No	No	

(c) final age-specific forecasts for planning fall inriver fisheries become available in June or July. In order to be consistent with the information available at the February PSC meeting, the general forecast was used in the calibrations for estimation of forecast abundance indices.

Forecasts for the Willamette spring stocks were obtained from ODFW (1987) and Willamette and Cowlitz spring stocks from ODFW and WDFW (1997). Age-specific forecasts are generally not available for the Columbia River summer stock. The 3-, 4-, and 5-year-old components of the terminal runs in 1994 and 1995 were obtained from the Biological Assessment Reports prepared by the Technical Advisory Committee (TAC 1994a, 1994b). Forecasts for 1996 and 1997 were obtained from the PFMC. Forecasts for the years 1985 through 1993 were computed on a post-hoc basis using the terminal run in the prior three years.

WCVI Wild and Hatchery. The WCVI stock is a major contributor to SEAK fisheries. The PSC chinook model includes both wild and hatchery components of the WCVI stock; however, because of data limitations, the calibration currently uses only a single forecast for the total wild and hatchery terminal run. The 1997 WCVI forecast relied upon a sibling regression of cohort size for the Robertson Creek Hatchery stock and a series of expansions to account for other WCVI production. Using the same methodology, a jackknife procedure was used to compute forecasts. The jackknife procedure was employed so as to utilize current knowledge regarding the form of the predictor and the current state of the data. Prior to 1987, the data necessary for the forecasts were not available.

The forecast for the total terminal run in 1997 was computed using a four-step process that successively predicted the (1) cohort size of the Robertson Creek Hatchery stock, (2) total wild and hatchery Barkley Sound cohort size, (3) total Barkley Sound terminal run size, and (4) the WCVI terminal run size.

The initial step of forecasting the abundance of the Robertson Creek Hatchery stock relies upon sibling regression models. Unlike the Columbia Upriver Bright forecasts, the regression models predict the total cohort size, rather than the terminal run. For example, for a particular brood, the age-2 cohort size is used to predict the age-3 cohort size, the sum of the age-2 and age-3 cohort sizes is used to predict the age-4 cohort size, and the sum of the age-2 through age-4 cohort sizes is used to predict the age-5 cohort size.

The Robertson Creek Hatchery forecast was then expanded for wild production in Barkley Sound by dividing the forecast for each age class by the proportion of the terminal run which was composed of wild fish for prior age classes of that brood. For example, the expansion factor for the 1992 brood (age-3 fish) in 1995 would be computed from the proportion of the terminal run of the age 2-fish in 1994 that was composed of wild production.

Since the PSC chinook model currently uses terminal run sizes to calibrate for the WCVI stock, the forecasted cohort size must be converted to an equivalent terminal run. In 1995 the Barkley Sound terminal run was computed by multiplying the cohort size by the average ocean exploitation rates estimated for the 1984 through 1990 broods, except for the WCVI troll fishery, where harvest rates were reduced to pre-1992 levels. The model used to estimate terminal runs was reviewed and accepted by a working group of the CTC in March, 1996.

The final step in the forecast is to expand the Barkley Sound forecast for other WCVI production. For age-3 fish, the expansion was based upon the relative terminal runs for the years 1985 through 1994, while the expansion for age-4 and age-5 fish relied upon the relative terminal runs for prior age classes of the same brood.

Puget Sound Stocks. Forecasts of the terminal run or escapement for Puget Sound stocks were obtained from reports of the former Washington Department of Fisheries (WDF) and WDFW (WDF et al. 1989, 1990, 1991, 1992, 1993, 1993a, 1993b, 1994a; Point No Point Treaty Council [PNPTC] 1993, 1994; WDFW et al. 1994(b)) as well as Northwest Indian Fisheries Commission (NWIFC) and Puget Sound Tribes (Puget Sound Tribes et al. 1985, 1987, 1988).

Postseason estimates of terminal run size are generally not available for Puget Sound stocks prior to May of the year following the return. Consequently, forecasts that generate projected abundance indices in February use the preseason forecasts for the previous year as the actual return and as the preseason forecast for upcoming year. Depending on when a calibration is run, the 1994 preseason forecast may be used as both the 1994 actual return and 1995 preseason forecast.

Fraser Late. The 1997 forecast for the Fraser Late stock was computed from a sibling regression of the terminal run. Using the same methodology, a jackknife procedure was used to (1) compute forecasts for the years 1985 through 1996 (2) allow the current data set to be used in the hindcasting.

4.1.2 Other Calibration Data

Many of the files used in the chinook model can be completed at the time of the calibration or have little effect upon the abundance index. For example, year-specific enhancement files (.ENH files) were not created for the hindcasting because hatchery releases are typically reported with minimal error by the time the release data are used in a calibration. Similarly, the same IDL, PNV, STK, and BSE files were used for all 10 calibrations (97-2; CTC 1997). Although the preseason agency forecasts are the major factor affecting the chinook model forecasts, year-specific versions of the following four files were also created:

Fishery Catch (.CEI File). Catch in a model fishery may be controlled by specifying either a ceiling or an exploitation-rate scale factor (see section below). For fisheries modeled with the ceiling algorithm, catch estimates were used for each calibration up to the projection year. For the 1987 calibration, for example, the estimated catch was used in the SEAK troll fishery in each year through 1986. Catches in the projection year were controlled using the exploitation rate scale factors in the .FP File below.

Chinook Nonretention Mortality (.CNR File). One CNR input file was created for each of the 10 model calibrations. In each file, postseason estimates of CNR were used for each year up to the projection year. Projected exploitation rates in the retention period relative to the model base period were used to predict CNR mortality in the projection year.

Exploitation Rates (.FP File). For model fisheries controlled by specification of an exploitation-rate scale factor, current estimates of the scale factor were used for each year up to the projection year. Exploitation rates in the projection year were computed using the standard calibration procedures for the chinook model (CTC 1997).

Maturation File (.MAT File). Maturation rates and adult equivalent factors from the most recent exploitation rate analysis were used up to the projection year minus 2. The 2-year lag was incorporated to reflect the delay in processing the CWT data as well as incomplete brood years.

4.2 Inseason Prediction

The CTC evaluated several potential inseason indicators of the chinook estimated abundance index in the SEAK troll fishery using data from 1980 through 1994, including the 400 boat index (400BI; Koenings et al. 1995), treaty chinook catch per permit for total troll, power troll, and hand troll, and catch per unit effort (CPUE) from the Fishery Performance Data (see Appendix B). These indicators were initially evaluated through single-regression models using estimated abundance indices as the dependent variable. These analyses did not include data from 1995 and 1996 because of the lack of a completed calibration for 1997, concerns regarding bias in the abundance index estimates for 1995 and 1996, and the reduced fit when recent years were included in the simple regression models without temporal factors (discussed further below). Most of the estimated indicators were highly correlated with the estimated abundance index and with each other. The chinook catch (adjusted for percent SEAK hatchery contribution) per power troll permit for boats landing catches during the first 5 days of the summer season was selected as the best indicator examined. This measure was termed the power troll statistic (PTS) and used in subsequent analyses of 1980 through 1996 data; data for 1995 and 1996 were included after a review of the calibration 9702 (Table 4).

Initially, the relationship of the PTS to abundance index was examined using a simple linear regression model of the log transformed variables, corresponding to Model 1 in Table 5. This simple model explained 65% of the variation in Ln(PTS). The estimated abundance index showed an upward trend for the period between 1980 and 1993; however, in recent years (1994-1996) it declined sufficiently to expose an apparent changing relation between fishing success and the estimated abundance index. Specifically, the PTS for given abundance indices appears to have increased in recent years.

Table 4. Power troll statistic (PTS) during the first 5 days of the summer season and estimated abundance indices, 1980-1996.

Year	Estimated Abundance Index	PTS
1980	1.03	20.6
1981	0.91	22.4
1982	1.21	26.6
1983	1.29	46.5
1984	1.30	24.3
1985	1.17	32.3
1986	1.30	29.7
1987	1.51	45.8
1988	1.78	67.2
1989	1.73	78.6
1990	1.81	65.7
1991	1.90	97.1
1992	1.75	74.9
1993	1.87	79.2
1994	1.60	71.3
1995	0.95	41.4
1996	0.90	42.3

Data in Table 4 were fit to Model 2 in Table 5 to explore the effect of changing efficiency, using β_1 to model a time trend in intercept and β_3 to model a time trend in slope. The coefficient for time trend in slope was not significant, so the reduced model with fixed slope was fit (Model 3, Table 5), ***which*** explained 89% of the variation in Ln(PTS). The exponentiated estimate of β_1 is roughly 1.05, implying that the PTS at a given level of abundance index increased about 5% per year. Median values for the PTS from Models 1 and 3 were obtained by exponentiating the expected model value obtained by substituting the estimates of the model parameters. Median values from Model 1 tend to overestimate PTS in early years and underestimate PTS in recent years; estimates of PTS from Model 3, which accounts for the time trend, are more accurate.

The jackknife procedure was applied to Model 3 for years 1987 through 1996. In each year, the inseason abundance index was computed as follows: (1) the regression coefficients were estimated; (2) the observed PTS inserted into Model 3, or set to zero; and (3) the resulting equation was solved for the abundance index. The mean square error (MSE) for each regression was also recorded for use in the jackknifing the Bayesian procedure presented in Section 4.3.5.

Table 5. Power troll statistic (PTS) regression models, parameter estimates and associated statistics.

PTS General Regression Model

$$Ln(x_i) = \beta_0 + \beta_1(i-1979) + \beta_2 Ln(\tau_i) + \beta_3(i-1979)\cdot Ln(\tau_i) + \eta_i, \quad i = 1980, 1981, \ldots, 1996$$

where

x_i = the PTS for year i

τ_i = the abundance index for year i

η_i = the random error for year i, iid $N(0, \sigma_\eta^2)$

Parameters	Estimates	Standard errors	Student's t	P values
Model 1: Fixed intercept, Fixed slope, 15 Degrees of freedom, R-squared of 0.65				
β_0 : Intercept	3.3351	0.1188	28.07	< 0.0001
β_1 : Not included	0	0		
β_2 : Slope	1.5375	0.2937	5.23	< 0.0001
β_3 : Not included	0	0		
σ_η : Random error	0.3089			
Model 2: Trending intercept, Trending slope, 13 Degrees of freedom, R-squared of 0.89				
β_0 : Intercept	2.9806	0.1206	24.72	<0.0001
β_1 : Intercept trend	0.4995	0.0108	4.62	<0.0001
β_2 : Slope	1.1240	0.5829	1.93	0.076
β_3 : Slope trend	0.0109	0.0470	0.23	0.821
σ_η : Random error	0.1874			
Model 3: Trending intercept, Fixed slope, 14 Degrees of freedom, R-squared of 0.89				
β_0 : Intercept	2.9653	0.0972	30.52	< 0.0001
β_1 : Intercept trend	0.0511	0.0094	5.45	< 0.0001
β_2 : Slope	1.2515	0.1799	6.96	< 0.0001
β_3 : Not included	0	0		
σ_η : Random error	0.1810			

4.3 Bayesian Prediction

The following steps were used to construct and illustrate the Bayesian prediction of the 1997 estimated abundance index for the SEAK fishery resulting from future calibration of the PSC chinook model:

(1) A large sample of 10,000 random pairs was generated from a bivariate density of 1997 PTS and estimated abundance index using Monte Carlo techniques. This joint density was sampled by the method of composition (Tanner 1996, 52-54) applied to two component densities: first, a prior density for the estimated abundance index based on a model for forecast error of the PSC chinook model and, second, a density for PTS, given the estimated abundance index based on a regression model. The bivariate density was conditioned on historical information consisting of PTS (1980-1996) from the fishery and statistics from the PSC chinook model, including estimated abundance indices (1980-1996) and estimated abundance index forecasts (1987-1997).

(2) The bivariate density was estimated from the random sample by the average shifted histogram (ASH) method (Scott 1992).

(3) Sections of the estimated bivariate density were obtained at selected potential values for 1997 PTS.

(4) Each section was normalized so the integral of the resulting section equaled 1, to describe a probability density for the relative frequency of potential estimated abundance indices from future calibrations of the current PSC chinook model given the preseason PSC chinook model forecast of the estimated abundance index and the PTS for 1997. Corresponding to the actual 1997 PTS, such a density provides a means of evaluating probabilities that the future estimated abundance index for 1997 from the current PSC chinook model will lie in selected intervals.

This approach follows the Bayesian calibration methodology of Aitchison and Dunsmore (1975), with the prior and bivariate densities being Bayes predictive densities (Press 1989; Aitchison and Dunsmore 1975); *both densities include uncertainty in their parameter values as well as uncertainty due to intrinsic annual variation in PSC chinook model forecast error and in fishing success given abundance.*

The unknown 1997 estimated abundance index and model parameters were viewed as random variables for which probability densities were derived from the historical data composed of PSC chinook model estimated fishery abundance indices for the SEAK fishery (τ), PSC chinook model forecasts of the estimated abundance index (z), and the PTS (x). The Bayesian approach required initial "prior" densities for unknowns to describe previous knowledge about their possible values. In this application, noninformative prior densities were used for model parameters, but an informative prior density was used for the unknown 1997 estimated abundance index that will derive from future calibrations of the current PSC chinook model. Model parameters were of secondary interest, and the data were adequate to delimit their values reasonably well. On the other hand, prediction of the 1997 estimated abundance index was of utmost interest, so a prior density for it was obtained from hindcasted abundance index forecasts of the PSC chinook model for years 1987 through 1996.

In deriving the bivariate density for the 1997 PTS and estimated abundance index (see Table 6 for definitions and notation for all variables and densities used), the assumptions largely paralleled those from the general theory of Aitchison and Dunsmore (1975). Each probability model describing the generation of paired observations, estimated abundance index and either corresponding forecasts or PTS, had one of two kinds of parameters (denoted as ψ and θ by Aitchison and Dunsmore): the first kind, ψ, described the prior probability density of the 1997 estimated abundance index based on the forecast abundance index; and the second kind, θ, described the density for PTS given the estimated abundance index using a regression model. The prior density was derived under an assumption of unbiased forecast abundance indices with lognormal errors and parameters were estimated by a single constant, $\psi = \sigma_f$, defining the variation in forecast errors. The regression model for PTS and estimated abundance index included the usual assumptions of independence, normality, and homogeneous variance of annual disturbances after appropriate transformations of variables; the parameters for the regression model were given by $\theta = (\beta_0, \beta_1, \beta_2, \sigma_\eta^{\ 2})$, where the first three coefficients described the relation of Ln (PTS) to Ln (estimated abundance index) with a trend in intercept through time (Table 5, Model 3), and the fourth parameter was a measure of annual variation.

4.3.1 Predictive Prior Density for 1997 Estimated Abundance Index Given 1997 Forecast

After testing the natural logarithms of relative forecast errors, Ln(r)'s, a generalized likelihood ratio statistic (*e.g.*, Mood and Graybill [1963, 298]) was used to test if the forecast abundance indices from the chinook model were plausibly unbiased for normality and independence (Table 7). The Shapiro-Wilk test of normality (W = 0.976, $p > 0.93$) of the transformed relative errors Ln(r) indicated that the normality assumption was reasonable. For normal random variables, a test for independence is equivalent to a test for correlation. The correlation test on Ln(r) indicated that the assumption of independence was somewhat suspect (*i.e.*, sample correlation coefficient = 0.329; one-tailed $p = 0.19$; two-tailed $p = 0.39$). The errors seemed to trend over time except for the 1994 forecast error.

Under the assumption of normality, the expected value of the relative forecast error E[r] is $\exp(\mu_f + \frac{1}{2}\sigma_f^{\ 2})$. If the independence assumption is adopted, a test for no bias in the forecast errors (*i.e.*, E[r]=1) is equivalent to testing the hypothesis of the equality constraint $\mu_f = -\frac{1}{2}\sigma_f^{\ 2}$. The maximum likelihood estimate for $\sigma_f^{\ 2}$ under this hypothesis is given by $\hat{\sigma}_f^2 = 2[1+(uss/n)]^{1/2} - 2 = (0.118345)^2$, where *uss* is the uncorrected

Table 6. Notation for variables and densities used in Bayesian estimation.

Line	Notation	Description	Source
1	τ	Estimated abundance index	Estimates of annual fishery abundance index for 1980 through 1996
2	z	Forecast abundance index	Abundance index for the forecast year, using data from previous years, from hindcasting the PSC chinook model (97-02)
3	x	Power troll statistic (PTS)	Treaty chinook catch per power troll permit by boats landing during first 5 days of summer troll fishery
4	$D_f = \{(z_i, \tau_i), i = 1987, 1988, \ldots, 1996\}$	Pairs of forecast and estimated abundance indices	Table 7
5	$D_c = \{(x_i, \tau_i), i = 1980, 1981, \ldots, 1996\}$	Pairs of PTS and estimated abundance index	Table 4
6	$r = z / \tau$ $\text{Ln}(r) \sim N(\mu_f, \sigma_f^{\,2})$	Relative forecast errors	Table 7, $\sigma_f^{\,2}$ drawn from density function, $p(\sigma_f \mid D_f)$
7	$p(\sigma_f \mid D_f) \propto \left(\frac{e^{-\sigma_f^{\,2}/8}}{\sigma_f} \right)^n e^{-\sum (Ln(r))^2 / 2\sigma_f^{\,2}}$	Posterior density for σ_f describing variation in forecast errors	Based on noninformative improper prior $p(\sigma_f) \propto 1$. Likelihood function for σ_f obtained by setting the parameter pair of the conjugate prior to zero.
8	$p(Ln(\tau_{1997}) \mid \sigma_f, z_{1997}) \sim N\left(\frac{\sigma_f^{\,2}}{2} + Ln(1.33), \sigma_f^{\,2} \right)$	Conditional density for $Ln(\tau_{1997})$ given σ_f and z_{1997}	
9	$p(Ln(\tau_{1997}) \mid D_f, z_{1997})$	Predictive density for $Ln(\tau_{1997})$	$= \int_0^\infty p(Ln(\tau_{1997}) \mid \sigma_f, z_{1997}) p(\sigma_f \mid D_f) d\sigma_f$
10	$p(\theta \mid D_c)$, $\theta = \begin{bmatrix} \hat{\beta}_0 \\ \hat{\beta}_1 \\ \hat{\beta}_2 \\ \sigma_\eta^{\,2} \end{bmatrix}$	Posterior density of parameter vector θ, for Model 3, Table 5	Calculated as the product of an inverse chi-square distribution and a conditional normal distribution (Tanner 1996, pg. 17-19)
11	$p(Ln(x_{1997}) \mid Ln(\tau_{1997}), \theta) \sim$ $N(\beta_0 + 18\beta_1 + \beta_2\, Ln(\tau_{1997}), \sigma_\eta^{\,2})$	Conditional probability density for $Ln(x_{1997})$ given $Ln(\tau_{1997})$ and $\sigma_\eta^{\,2}$	
12	$p(Ln(x_{1997}) \mid Ln(\tau_{1997}), D_c)$	Predictive density for $Ln(x_{1997})$	$= \int_\theta p(Ln(x_{1997}) \mid Ln(\tau_{1997}), \theta) p(\theta \mid D_c) d\theta$
13	$p(Ln(x_{1997}), Ln(\tau_{1997}) \mid D_c, D_f, z_{1997})$	Bivariate predictive density for PTS and estimated abundance index	$= p(Ln(x_{1997}) \mid Ln(\tau_{1997}), D_c)$ $* \, p(Ln(\tau_{1997}) \mid D_f, z_{1997})$

Table 7. Estimated abundance indices, hindcasted PSC chinook model forecasts, and relative forecast errors (ratio of preseason forecast to index), 1987 through 1996.

Year	Abundance Index		Forecast Errors	
	Estimated, τ	Forecast, z	Relative Error (r)	Ln (r)
1987	1.51	1.89	1.252	0.22447
1988	1.78	2.01	1.129	0.12152
1989	1.73	1.83	1.058	0.05619
1990	1.81	1.99	1.099	0.09481
1991	1.90	1.91	1.005	0.00525
1992	1.75	1.71	0.977	-0.02312
1993	1.87	1.76	0.941	-0.06062
1994	1.60	1.82	1.138	0.12883
1995	0.95	0.81	0.853	-0.15943
1996	0.90	0.79	0.878	-0.13036

sum of squares of Ln(r). The maximum likelihood estimates for μ_f and σ_f^2 without the equality constraint are the sample mean ($\hat{\mu}_f$) and variance ($\hat{\sigma}_f^2$) of Ln(r) (Table 8).

The generalized likelihood ratio statistic λ is computed as the ratio of likelihood functions (for parameters μ_f and σ_f) of a normal sample. The likelihood function in the numerator is maximized with the constraint, *i.e.*, $\mu_f = -\frac{1}{2}\bar{\sigma}_1^2$ and $\sigma_f^2 = \bar{\sigma}_f^2$, and the likelihood function in the denominator is maximized without the constraint, *i.e.*, $\mu_f = \hat{\mu}_f$ and $\sigma_f^2 = \hat{\sigma}_f^2$. The statistic -2 Ln λ is then approximately distributed as a chi-square random variable with 1 degree of freedom. The significance level of this test was 0.38, indicating the assumption of unbiased chinook model forecasts was tenable.

If the forecast abundance indices are unbiased and relative errors lognormally distributed, a single parameter (say σ_f) will describe the error distribution. If a noninformative improper prior is used for σ_f, *viz.*, $p(\sigma_f) \propto 1$, the posterior for σ_f^2 is $p(\sigma_f \mid D_f)$ (Table 6, line 7). This posterior density is simply the likelihood function for σ_f obtained by setting the parameter pair of the conjugate prior to zeroes; *e.g.*, Gelman et al. (1995, 37-38). Using the sample size (n=10) and uncorrected sum of squares (0.140546) of the logarithm-transformed relative forecast errors, the normalized version of the posterior density for σ_f was a skewed distribution with the mode at maximum likelihood estimate (Figure 3).

To draw samples from this posterior density, the transformation method (Press et al. 1989) was used. The distribution function (*i.e.*, the integral of the density function in

Table 8. Sample statistics for logarithm-transformed relative forecast errors of estimated abundance indices by PSC chinook mode, 1987 through 1996.

Statistic	Symbol, estimator or test statistic	Value
Sample size	N	10
Mean, μ_f	$\hat{\mu}_f = \mu_2 =$ sample mean of Ln(r)'s	0.025754
Standard deviation, σ_f	$\hat{\sigma}_f = \sigma_2 =$ standard deviation of Ln(r)'s	0.115721
Variance, $\sigma_f^{\ 2}$	$\hat{\sigma}_f^{\ 2} = \sigma_2^{\ 2} =$ sample variance	0.013390
Uncorrected sum of squares	$\text{USS} = \sum (\text{Ln}(r)^2)$	0.140546
Shapiro-Wilk, test for normality of Ln(r)	W p-value	W=0.976 $p > 0.93$
Correlation test for independence of Ln(r)'s	r = sample correlation coefficient one-tailed p value two-tailed p value	0.329 $p = 0.19$ $p = 0.39$
-2 Log-likelihood ratio, test of unbiased errors	$-2\,\text{Ln}(\lambda) \sim \chi_1^{\ 2}$ significance level	$-2\text{Ln}(\lambda) = 0.776$ 0.38

Table 6, line 7, up to the evaluation point in the range of σ_f) corresponding to the posterior density was evaluated at 500 equispaced points in the range of σ_f between 0.001215 and 0.607500. The integrations for evaluating the distribution function were performed with subroutine QSIMP (parameters eps = 10^5 and J_{max}= 20) (Press et al. 1989). At σ_f =0.001215, the cumulative distribution function was approximately zero; and at 0.607500, the cumulative distribution function was 0.99999. For each draw, a uniform random number between 0 and 1 was generated by subroutine RAN2 (Press et al. 1989) to represent a point along the cumulative probability density. This point corresponded to a value of σ_f , which was set to the rearest of the 500 equally spaced points.

Assuming forecasts are unbiased and relative forecast errors are lognormally and independently distributed, the product of the conditional normal density for Ln(τ_{1997}), $p(Ln(\tau_{1997}) \mid \sigma_f, z_{1997})$ (Table 6, line 8) and the posterior density for σ_f , $p(\sigma_f \mid D_f)$ (Table 6, line 7) was integrated over the range of σ_f to obtain the predictive prior density for 1997 estimated abundance index, $p(Ln(\tau_{1997}) \mid D_f, z_{1997})$ (Table 6, line 9), using the 1997 forecast abundance index of $z_{1997} = 1.33$.

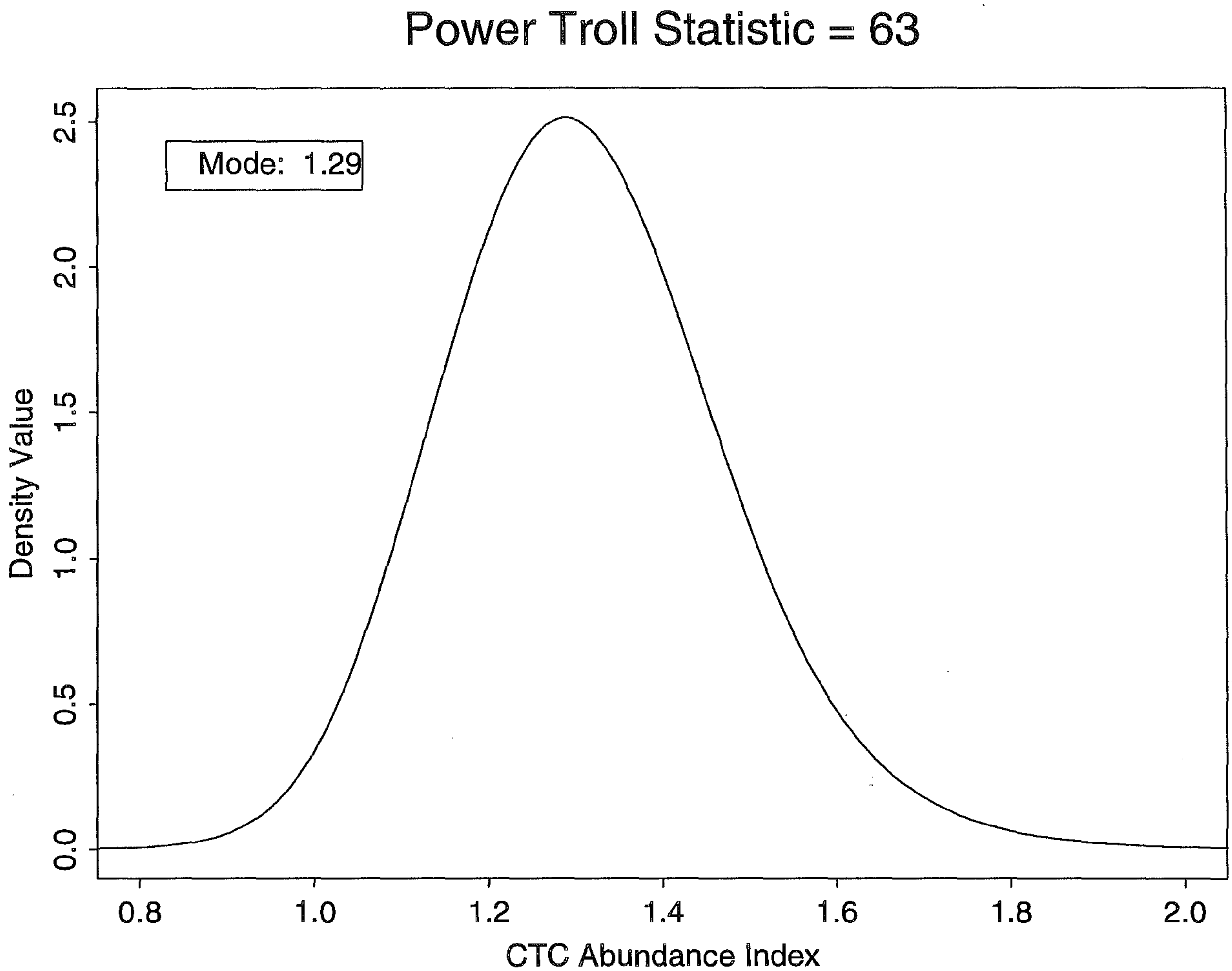

Figure 3. Posterior density, $p(\sigma_f \mid D_f)$, for the parameter (σ_f) describing lognormal variation of unbiased preseason forecasts that results from a noninformative prior and the chinook model forecasts of estimated abundance indices for 1987 through 1996.

4.3.2 Predictive Density for PTS Given Estimated Abundance Index

If a noninformative prior for the unknown parameters is used, their posterior density, $p(\theta \mid D_c)$, is the product of an inverse chi-square distribution and a conditional normal distribution; e.g., Tanner (1996, 17-19). The product of this posterior density and the conditional density for 1997 PTS, $p(Ln(x_{1997}) \mid Ln(\tau_{1997}),\theta))$, was integrated over the range of the unknown parameters to obtain the predictive density for PTS given the abundance index, $p(Ln(x_{1997}) \mid Ln(\tau_{1997}), D_c)$ (Table 6, line 12). This predictive density was used in deriving the joint predictive density for 1997 PTS and estimated abundance index.

4.3.3 Joint Predictive Density for PTS and Estimated Abundance Index

The joint predictive density for PTS and estimated abundance index $p(Ln(x_{1997}), Ln(\tau_{1997}) \mid D_c, D_f, z_{1997})$ was obtained as the product of the predictive density for $Ln(x_{1997})$ given $Ln(\tau_{1997})$ (Table 6, line 12) and the predictive density for $Ln(\tau_{1997})$ (Table 6, line 9). Ten thousand pairs of values from this joint predictive density were obtained by Monte Carlo sampling from the individual predictive densities using the method of composition described in Tanner (1996, 52-54). Standard random deviates required in the Monte Carlo sampling were generated by subroutines from the RANLIB library (Brown and Lovato 1993): normal deviates, subroutines SETGMN and GENMN; and chi square deviates, subroutine GENCHI. Generation of random deviates from $p(\sigma_f \mid D_f)$ was described in section 4.3.1.

The algorithm used was as follows:

For the *i*th pair of values:

(1) Draw random $\sigma_{f,i}^{*}$ from the posterior distribution, $p(\sigma_f \mid D_f)$.

(2) Draw $Ln(r_{1997,i})^{*} \sim N\left(-\frac{1}{2}\sigma_{f,i}^{2*}, \sigma_{f,i}^{2*}\right)$.

(3) Compute $Ln(\tau_{1997,i})^{*} = Ln(1.33) - Ln(r_{1997,i})^{*}$.

Steps 1 through 3 comprise a draw from the predictive prior density for the estimated abundance index (Table 6, line 9).

(4) Draw $\beta_{0,i}^{*}, \beta_{1,i}^{*}, \beta_{2,i}^{*}, \sigma_{\eta,i}^{2*}$ from the posterior density, $p(\theta \mid D_c)$, for the four parameters of regression Model 3 of PTS, abundance index and year (Tanner 1996, 17-19).

(5) Draw PTS regression error $\eta_i^{*} \sim N(0, \sigma_{n,i}^{2*})$.

(6) Compute $Ln(x_{1997,i})^{*} = \beta_{0,i}^{*} + 18\beta_{1,i}^{*} + \beta_{2,i}^{*} Ln(\tau_{1997,i})^{*} + \eta_i^{*}$.

Steps 4 through 6 comprise a draw from the predictive density for PTS given estimated abundance index (Table 6, line 12).

(7) Repeat steps 1 through 6 until 10,000 sample pairs are obtained.

A sample of 10,000 pairs of logarithm-transformed values of abundance index and PTS were placed in 500 x 500 rectangular bins with the bins extending beyond the range of the generated observations of either variate by 5% of its range. The counts were processed using the averaged shifted histogram (ASH) method (Scott 1992, Chapter 5) to estimate the joint density. Specifically, the ASH2 algorithm was used with the number of bins for either variate set to 500 and counts from 50 x 50 = 2500 rectangular adjacent bins averaged to produce the smoothed density estimate.

Sections through the joint density corresponding to PTS values of 30-130 fish per permit (in 10 fish increments) were obtained to provide the estimated posterior densities for the 1997 estimated abundance index corresponding to potential 1997 PTS values. Each section comprised the 500 ASH smoothed values from the Ln-transformed abundance index bins at the level of the logarithm-transformed PTS bin nearest that for the specified PTS value; the 500 smoothed values were normalized to a density by dividing each by the product of their sum times the bin width. The resulting density from each section was transformed to the original scale of the abundance index (from its Ln) by dividing each of the 500 normalized density values by its exponentiated bin value for the Ln-transformed abundance index. The modes, medians and means, forecast line, and probability contours were plotted from these posterior densities for the untransformed abundance index.

4.3.4 Jackknifing the Bayesian Procedure

Jackknifed estimates from the Bayesian procedure for the years 1987 through 1996 require for each of these years a measure of the variance of the chinook model forecast error and estimates of the coefficients of Model 3 in Table 5 (the inseason predictor). The jackknifed measure of model forecast error was calculated as the uncorrected sum of squares (USS) of the Ln transformed ratios of the model forecast to the postseason abundance index ($Ln(z_i/\tau_i)$) for all years, except the jackknifed year (USS). The coefficients of Model 3 were also estimated by jackknifing this relationship for years 1987 through 1996 (using the 1980 through 1996 data series for the linear regressions). These data (Table 9) were then input into the Bayesian program to generate jackknifed Bayes estimates for each year.

Table 9. Data input for jackknifing Bayesian estimates of the abundance index, including the coefficients and variance for Model 3 in Table 5; the jackknifed values for the USS; and the Ln transformed values for the PTS (x) and the forecast abundance index (τ).

Year	Intercept	Slope	Year	Variance	USS	Ln PTS (x)	Ln (τ)
1987	2.969514	1.259346	0.05076882	0.034922340	0.09016064	3.825102	0.636577
1988	2.964368	1.233325	0.05133445	0.034936395	0.12577872	4.207690	0.698135
1989	2.965627	1.202288	0.05124824	0.031719218	0.13738833	4.364589	0.604316
1990	2.962493	1.275220	0.05116968	0.034647876	0.13155764	4.185804	0.688135
1991	2.978417	1.186904	0.05336520	0.031800234	0.14051860	4.575867	0.647103
1992	2.964349	1.254271	0.05116258	0.035252053	0.14001151	4.316458	0.536493
1993	2.955037	1.277283	0.05201846	0.034495224	0.13687081	4.372507	0.565314
1994	2.960038	1.255509	0.05190365	0.035019059	0.12394825	4.267072	0.598837
1995	2.965377	1.255324	0.05086103	0.035263882	0.11512895	3.722885	-0.210721
1996	2.967336	1.299242	0.04858173	0.034962605	0.12355195	3.745672	-0.235722

4.4 Evaluation Criteria

The accuracy and precision of predicted abundance indices compared with estimated abundance indices were evaluated using the following statistics:

Mean Percent Error (MPE): The MPE of a predictor is the average deviation of the predicted from the estimated abundance index expressed as a percent of the estimated abundance index, an examination of potential bias.

Mean Absolute Percent Error (MAPE): The MAPE of a predictor is the average absolute deviation of the predicted index expressed as a percent of the estimated abundance index, the observed average error, a measure of uncertainty.

Maximum Positive and Negative Errors: Largest positive and negative percent errors of the predicted from the estimated abundance index, the maximum range of the observed errors.

5.0 RESULTS

5.1 Effect of Calibration Year on Chinook Model Abundance Projections

The accuracy of forecast abundance indices was evaluated by examining the effect of the number of years between the forecast and the estimated abundance indices. Results are presented in Tables 10 and 11. For example, Table 10 shows that the current estimated abundance index for the SEAK troll fishery is 1.51 in 1987; the preseason forecast abundance index projection would have been 1.89; the estimated abundance index for 1987 in 1988 would have been 1.59; and the estimated abundance index in 1989, two years later, would have been 1.52. Percentage deviations from the estimated abundance indices are provided in Table 11. The MPE was +3% in the year of the projection and -1% or 0 for the other years.

5.2 Inseason Prediction

A number of measures of catch and effort data were examined as inseason predictors of the estimated abundance index. The regression relationship between PTS and the estimated abundance index was selected as the best inseason predictor (Appendix B). Because of an apparently changing relationship between fishing success and the estimated abundance index (Figure 4), alternate models that included coefficients for time trends in the slope or intercept were also examined. Models that included time trends (Table 5) increased the percentage of variation explained from 65% with the simple model (Model 1) to 89% (Models 2 and 3). Because the coefficient for time trend in slope was not significant (Model 2), the best model was Model 3, which assumes fixed slope, but a time trend in the intercept. When compared with the fixed model (Model 1), this trending model (Model 3) greatly reduces the deviation between observed and expected values of the PTS and the estimated abundance index relative (Figure 4).

Table 10. Preseason forecast (z) and estimated abundance indices (τ) for the SEAK troll fishery by the number of years since the forecast abundance index was initially made.

	Abundance Index		Years After Forecast Year									
Year	Est. τ	Forecast. z	1	2	3	4	5	6	7	8	9	10
1987	1.51	1.89	1.59	1.52	1.53	1.53	1.53	1.53	1.53	1.49	1.53	1.51
1988	1.78	2.01	1.75	1.78	1.78	1.78	1.78	1.78	1.75	1.78	1.78	
1989	1.73	1.83	1.71	1.72	1.73	1.73	1.73	1.71	1.73	1.73		
1990	1.81	1.99	1.75	1.80	1.80	1.81	1.80	1.81	1.81			
1991	1.90	1.91	1.86	1.90	1.90	1.89	1.90	1.90				
1992	1.75	1.71	1.78	1.74	1.73	1.74	1.75					
1993	1.87	1.76	1.91	1.77	1.87	1.87						
1994	1.60	1.82	1.49	1.60	1.60							
1995	0.95	0.81	0.91	0.95								
1996	0.90	0.79	0.90									

Table 11. Percent deviations of forecast abundance index for the SEAK troll fishery from the estimated index by the number of years since the forecast abundance index was initially made.

	Abundance Index		Years After Forecast Year								
Year	Est.(τ)	Forecast (z)	1	2	3	4	5	6	7	8	9
1987	1.51	+25%	+5%	+ 1%	+ 1%	+1%	+1%	+1%	+1%	-2%	+1%
1988	1.78	+13%	-2%	0%	0%	0%	0%	0%	-1%	0%	
1989	1.73	+6%	-1%	-1%	0%	0%	0%	-1%	0%		
1990	1.81	+10%	-3%	0%	0%	0%	0%	0%			
1991	1.90	+1%	-2%	0%	0%	0%	0%				
1992	1.75	-3%	+2%	-1%	-1%	0%					
1993	1.87	-6%	+2%	-5%	0%						
1994	1.60	+13%	-7%	0%							
1995	0.95	-15%	-5%								
1996	0.90	-13%									
MPE		+3%	-1%	-1%	0%	0%	0%	0%	0%	-1%	0%
MAPE		10%	3%	1%	0%	0%	0%	0%	1%	1%	0%
Max. (+) Error		+25%	+5%	+1%	+1%	+1%	+1%	+1%	+1%	0%	+1%
Max. (-) Error		-15%	-7%	-5%	-1%	0%	0%	-1%	-1%	-2%	0%

5.3 Bayesian Model for 1997

With the inseason catch rate regression model having a trending intercept to 1997, the joint density for 1997 logarithm-transformed abundance index and the PTS rate was symmetric and approximately centered at the 1997 forecast abundance index (Figures 3 and 5). With transformation to the original scale of measurement, the density became asymmetric and shifted leftward (Figure 6, left panel). The mode, median, and mean lines are ordered left to right and intersect the forecast abundance index for 1997 between PTS values of 60 to 80: the mean line crosses first, then the median line, and finally the mode line. The modal abundance index is always less than the median or mean index.

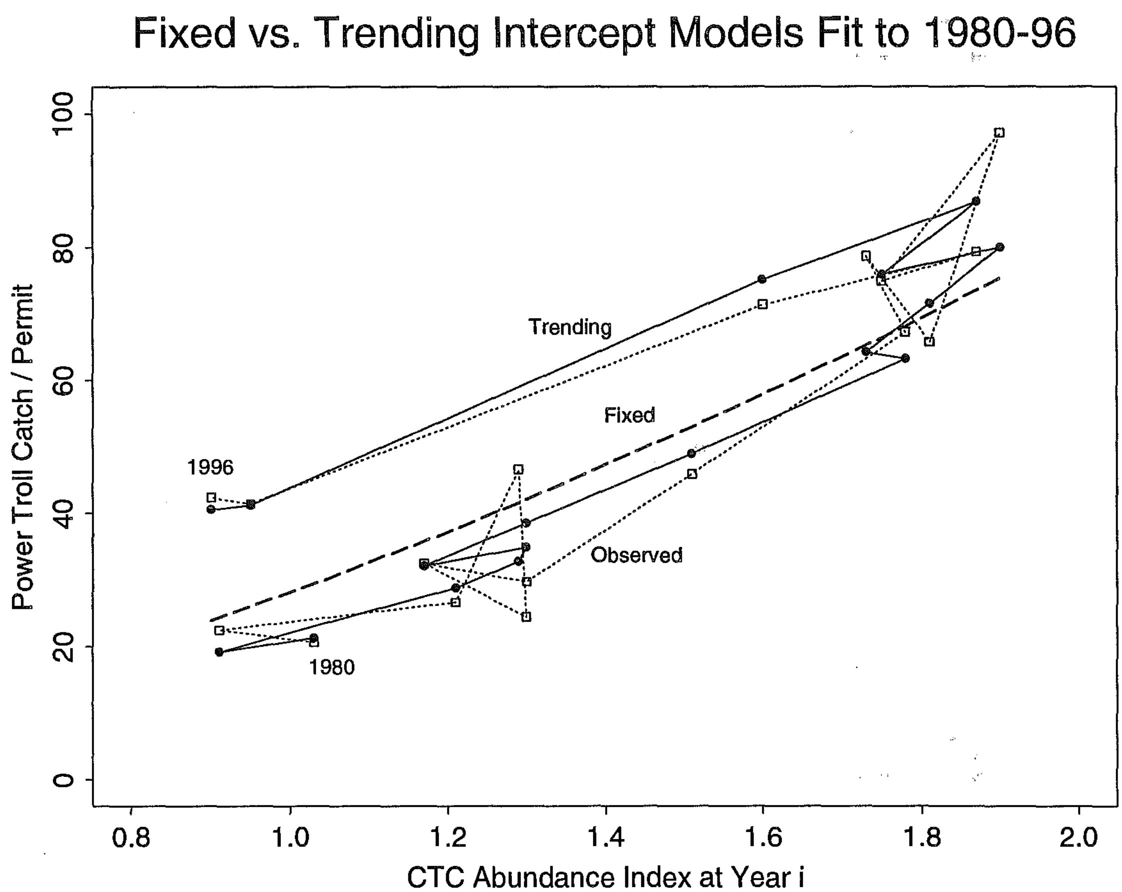

Figure 4. Observed power troll statistic (PTS) versus estimated abundance index (····) and estimated median values for fixed (---) and trending (●—●) slope models, 1980-1996 (Note that the observed and trending intercept median values are serially connected with dotted and solid line segments, respectively.)

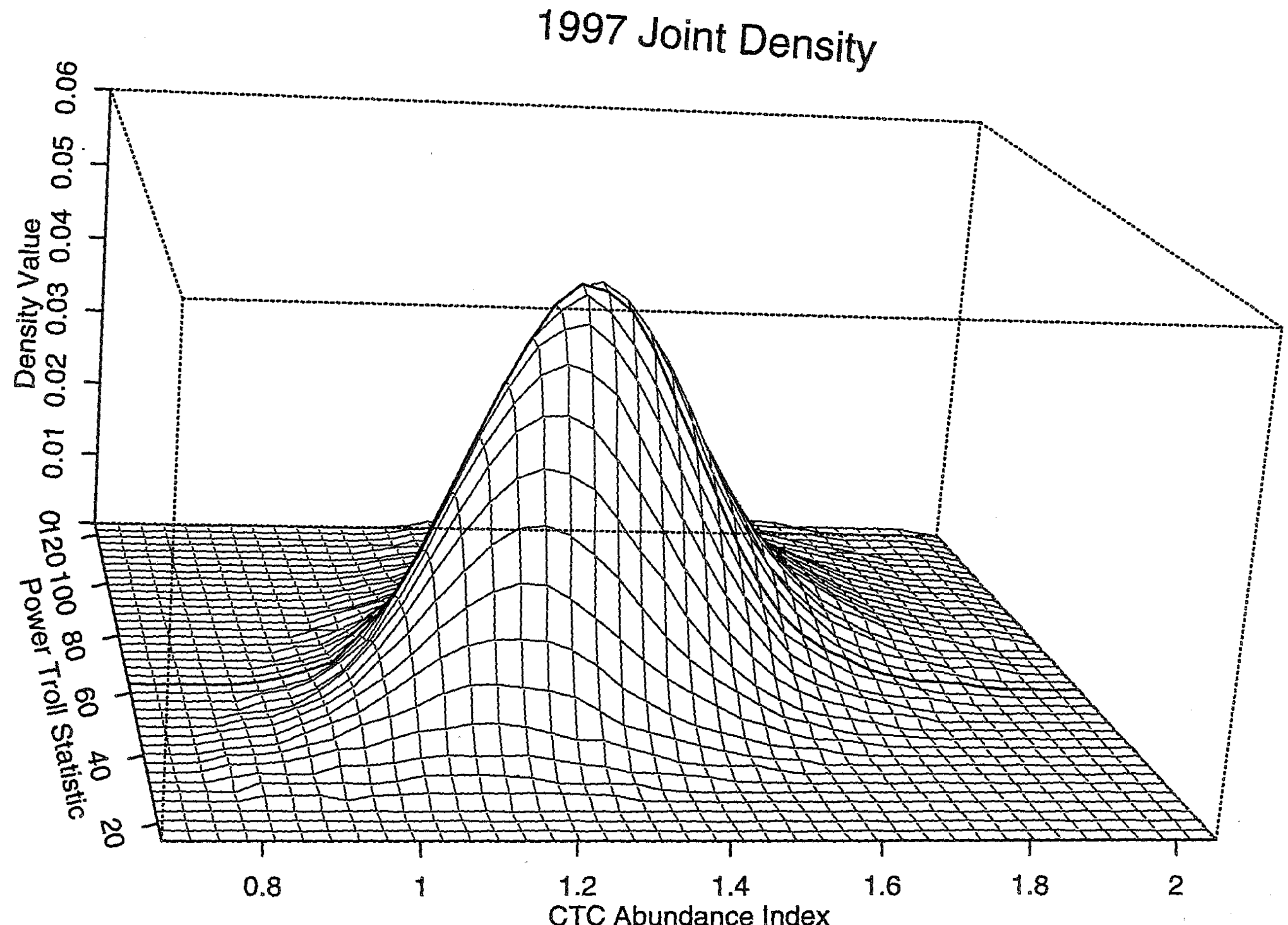

Figure 5. The joint density for prediction of the 1997 power troll statistic (PTS) and estimated abundance index (τ).

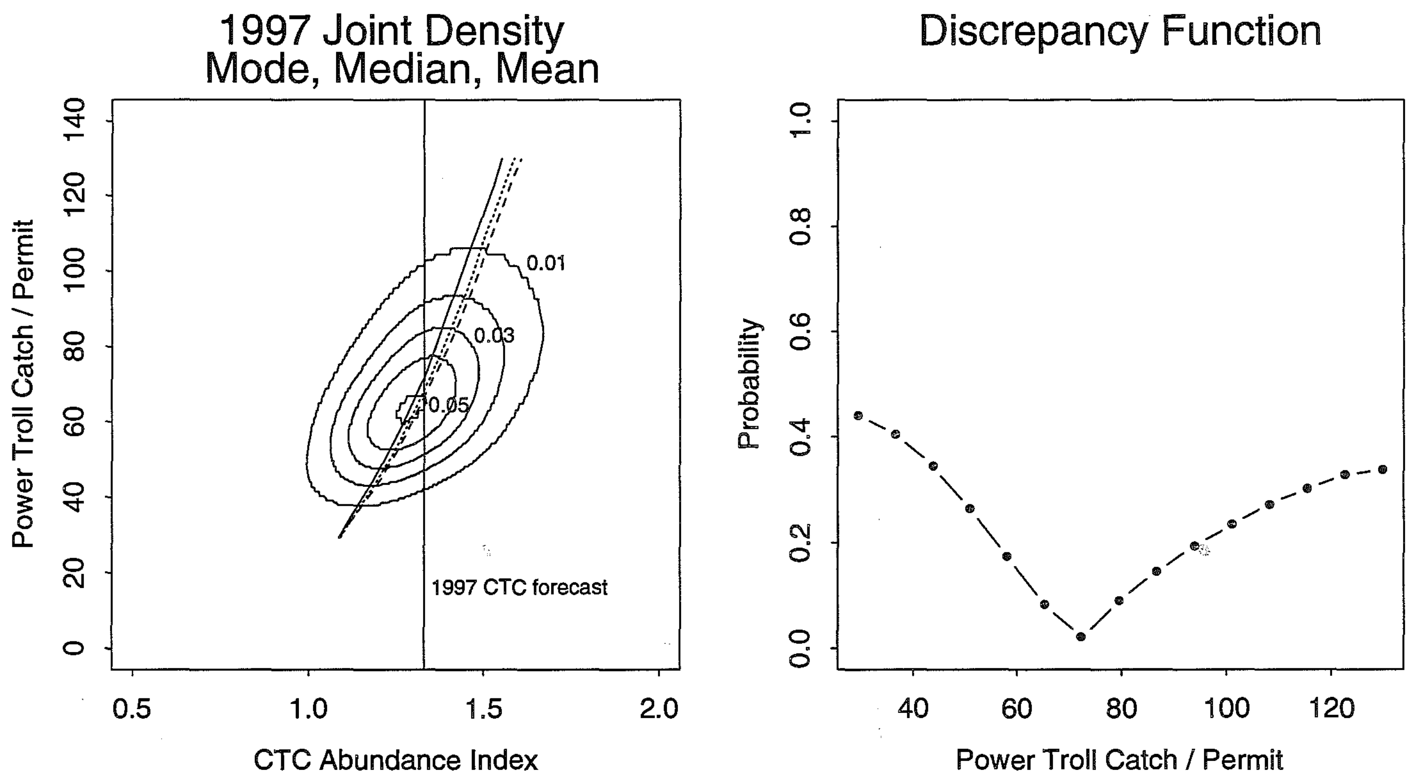

Figure 6. Probability density contours and the mode (—), median (----), and mean (....) lines from the 1997 joint density for prediction of the power troll statistic (PTS) and estimated abundance index (left); and the associated discrepancy function, or probability that the 1997 estimated abundance index from future calibrations with the current PSC chinook model will lie between the mode and the forecast value given a PTS statistic in a range of potential values (30-130 fish per permit) (right).

The discrepancy function, or proportions of the updated conditional densities (on unknown 1997 inseason catch rate) for the 1997 abundance index that occur between the mode and the projected abundance from the chinook model (Figure 6, right panel), increases with distance from an inseason catch rate in the vicinity of 72 fish per permit; that rate corresponds to the crossing of the mode and the projected abundance from the chinook model (Figure 6, left panel).

5.4 Comparison of Model Performance

Predicted fishery abundance indices from the SEAK troll fishery from the hindcasting exercises are provided in Table 12 and Figure 7. For the period from 1987 through 1996, percent errors in the forecast abundance index ranged from -15% to +25% (Table 12); errors in predictions from the PTS regression model ranged from -8% to +22%; and errors in predictions from the Bayesian model ranged from -13% to +15. The PTS and Bayesian predictions exhibited smaller MAPE and lesser ranges of maximum errors than the forecast abundance index. The Bayesian model exhibited the smallest MPE and the smallest maximum positive deviation. The direction and deviation of the PTS model differed from the forecast abundance index and the Bayesian prediction in 5 of the 10 years.

Forecast abundance indices and predicted abundance indices by the Bayesian method exhibited similar patterns of deviation from estimated abundance indices. A positive value was present in the first 5 years and a negative value in 4 of the last 5 years (Figure 8).

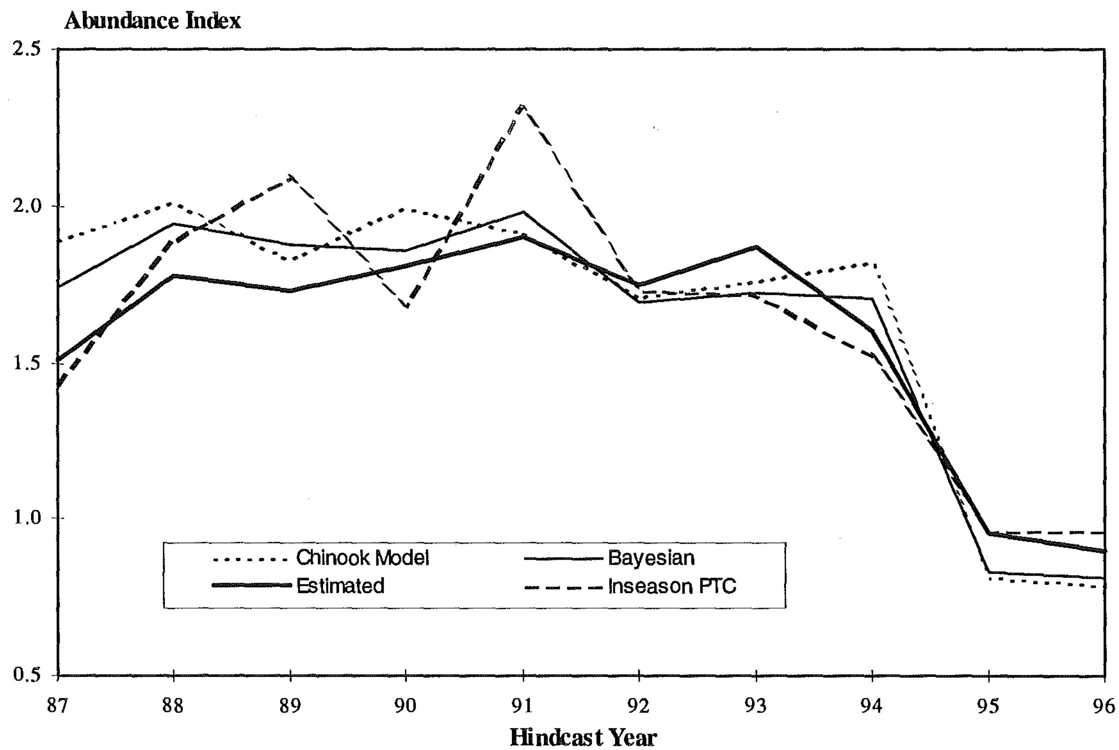

Figure 7. A comparison between predicted abundance indices for the SEAK troll fishery from hindcasting exercises.

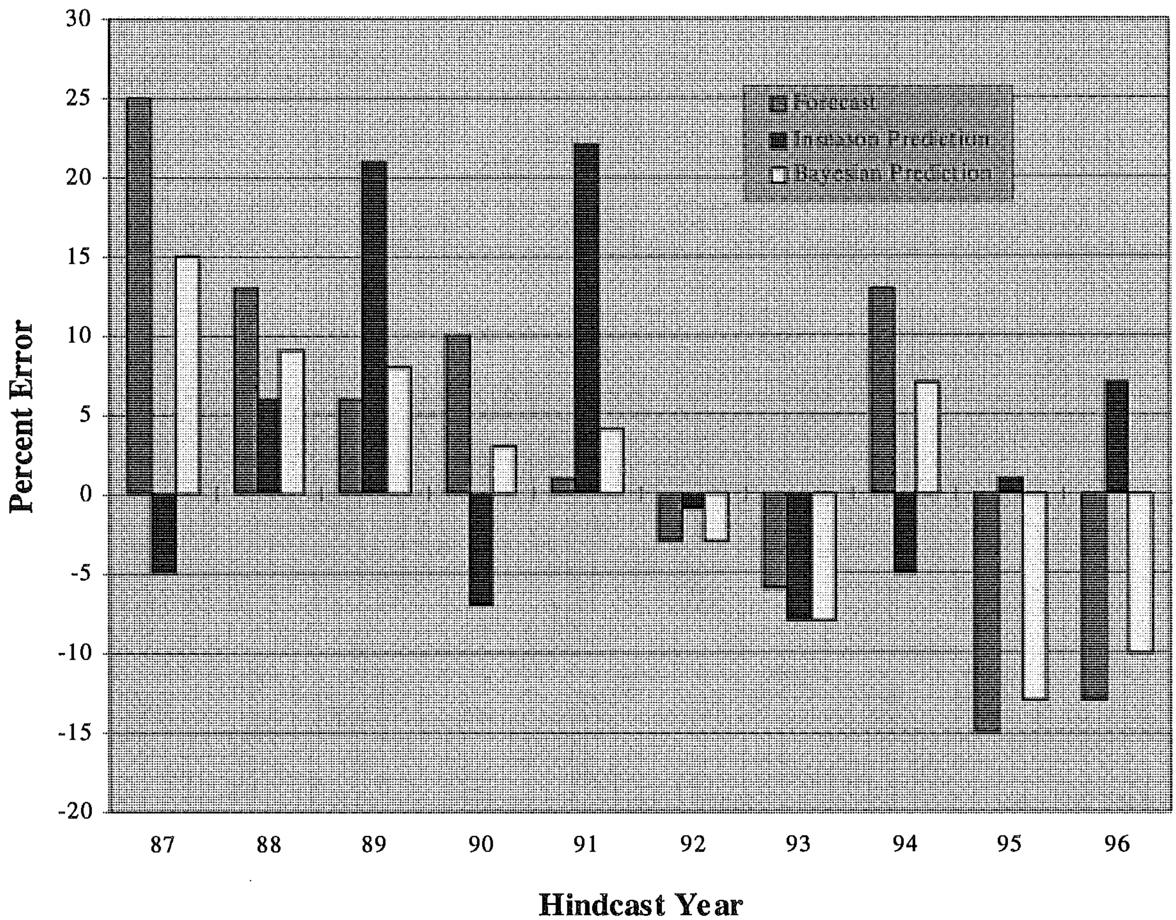

Figure 8. Deviations in abundance as predicted by the chinook model forecast and inseason with the power troll statistic and the Bayesian method.

Table 12. MPE and MAPE for predictions of the abundance indices obtained from hindcasting with the chinook model, the inseason catch rate regression model, and the Bayesian model.

Year	Estimated Abundance Index	Chinook Model		Inseason PTS Model		Bayesian Model	
		Forecast Abundance Index	% Error	Predicted Abundance Index	% Error	Predicted Abundance Index	% Error
1987	1.51	1.89	+25%	1.43	-5%	1.74	+15%
1988	1.78	2.01	+13%	1.88	+6%	1.94	+9%
1989	1.73	1.83	+6%	2.09	+21%	1.88	+8%
1990	1.81	1.99	+10%	1.68	-7%	1.86	+3%
1991	1.90	1.91	+1%	2.31	+22%	1.98	+4%
1992	1.75	1.71	-3%	1.73	-1%	1.69	-3%
1993	1.87	1.76	-6%	1.72	-8%	1.72	-8%
1994	1.60	1.82	+13%	1.52	-5%	1.70	+7%
1995	0.95	0.81	-15%	0.96	+1%	0.83	-13%
1996	0.90	0.79	-13%	0.96	+7%	0.81	-10%
MPE			+3%		+3%		+1%
MAPE			10%		8%		8%
MAX +			+25%		+22%		+15%
MAX -			-15%		-8%		-13%

6.0 DISCUSSION AND RECOMMENDATIONS

The strength of the Bayesian methodology evaluated in this paper lies in its explicit recognition of the uncertainty associated with both the forecast abundance index and inseason fishery performance indicators of chinook abundance. The CTC believes that the mode from the Bayesian posterior distribution provides the best point estimate (e.g., lowest average percent error) of the methods evaluated for estimating the abundance of chinook in the SEAK fishery. As recommended by the Ad Hoc Workgroup in 1995, considering information from both the preseason forecast and fishery performance data should provide a more accurate estimate of the chinook abundance available to the SEAK troll fishery.

With adoption of the Bayesian methodology, the CTC has an evaluation of the uncertainty surrounding predictions of the estimated chinook abundance index. This uncertainty provides additional information that may be important for interpretation of the abundance index estimates and future management of PSC fisheries. For example, the dispersion of the prior (PSC model forecasts) and posterior (Bayesian approach) probability distributions about the mode reflects the degree of uncertainty associated with either indicator of abundance. If the dispersion is small (i.e., distribution narrowly centered about the mode), the confidence is high; therefore, the true abundance index (i.e., estimated as the PSC model index generated at least two years after the initial preseason abundance forecast) is likely to lie very close to the mode. An increased uncertainty about the true abundance index is reflected by a high dispersion of the probability distribution about the mode. *The CTC recommends that the PSC consider how the new information on the uncertainty of the estimated abundance index could be usefully employed in management strategies.*

The prior probability density has a dispersion at least as great as that of the Bayesian posterior; so it always indicates equal or greater uncertainty regarding abundance at the time of the fishery. Regardless of the degree of disagreement between the forecast and fishery performance estimates of abundance, the Bayesian posterior density can never have a greater dispersion than the forecast prior density; therefore, at least the apparent uncertainty in abundance can never increase with updating by fishery performance.

The shape of either distribution may change each year as new data are added and/or additional relationships incorporated. The current analysis of probability distributions relies upon limited data sets: 10 years for the hindcasted PSC model forecasts and 17 years for the power troll statistic. Currently available data sets are limited, future improvements in the PSC model forecasts are likely, and improved measures of inseason fishery performance may be identified. The Bayes predictive prior and PTS regression models are derived from plausible assumptions regarding the error structure of data, but the assumptions are difficult to verify, given the limited information. With the assumed error structure, the Bayesian method does incorporate the greater uncertainty in model parameters resulting from the limited span of observation. The performance of the Bayesian modes, as estimates of abundance indices in the hindcasting experiment, shows that the method was reasonably robust. Further analysis could examine alternative data transformations. *For these reasons the CTC recommends reevaluation of procedures to estimate abundance of chinook available to the SEAK fishery using inseason information prior to the 1999 fishing season.*

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Appendix A

Forecasts of stock abundance used to hindcast the PSC chinook model

Model Stock	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Fraser Late											
Age 3	25.2	26.0	22.2	25.7	23.7	23.6	22.4	25.9	25.3	25.1	44.7
Age 4	13.9	29.4	5.6	109.5	13.0	74.7	78.8	119.7	9.4	25.9	32.9
Age 5	14.5	4.1	3.0	1.6	14.1	3.4	9.4	7.2	10.3	1.1	2.4
WCVI Hatchery and Wild											
Age 3	120.4	36.0	104.1	139.0	129.1	117.9	21.9	10.3	0.0	18.5	17.4
Age 4	19.9	172.3	92.8	159.1	134.9	150.2	138.2	166.1	10.7	0.6	93.0
Age 5	19.4	7.4	61.5	39.1	58.6	63.4	62.7	64.8	55.5	6.2	8.9
Nooksack Fall	132.1	101.4	79.4	75.1	80.0	61.2	53.5	46.6	42.0	28.7	34.0
PS Fall Fingerling and Yearling	74.9	73.0	83.0	98.5	88.3	87.9	70.9	21.7	25.0	62.8	78.7
PS Natural	22.4	27.1	32.8	42.8	37.4	34.9	35.5	69.6	64.4	19.1	19.0
Skagit Summer/Fall Wild	14.6	24.8	20.4	17.5	16.8	16.8	14.0	8.1	7.6	7.1	6.4
Stillaguamish Summer/Fall Wild	0.6	0.5	2.0	1.8	1.2	1.0	1.1	0.8	1.0	1.0	0.9
Snohomish Summer/Fall Wild	9.4	7.8	7.9	7.9	7.6	7.5	4.9	4.5	4.3	4.2	5.2
Columbia Upriver Bright	450.0	500.0	250.0	170.0	85.0	70.0	74.0	70.0	103.7	88.9	166.4
Mid-Columbia Bright Hatchery	41.7	68.7	50.0	60.0	40.0	45.0	27.0	30.0	25.0	40.8	72.1
Spring Creek Hatchery	9.1	6.5	30.0	35.0	50.0	35.0	22.0	20.0	17.4	27.6	21.9
Lower Bonneville Hatchery and Cowlitz Fall Hatchery	200.0	275.0	100.0	75.0	75.0	130.0	85.0	40.0	35.8	37.7	54.2
Lewis River Wild	29.2	43.3	30.0	30.0	15.0	11.0	14.0	15.0	12.4	8.8	7.5
Willamette Spring Hatchery											30.0
Age 4	42.0	51.9	50.1	81.1	52.7	73.2	51.3	42.0	17.4	23.6	-
Age 5	35.9	46.7	53.3	47.8	58.0	32.9	19.6	33.4	33.3	17.7	-
Age 6	0.5	0.7	0.6	1.6	2.1	2.7	2.2	2.2	.5	0.8	-
Spring Cowlitz Hatchery	-	32.0	16.1	18.6	19.7	26.6	21.3	12.3	4.7	4.5	4.6
Columbia Upriver Summer	18.0	20.0	20.3	22.4	21.0	19.1	14.3	13.3	8.8	16.8	16.7
Oregon Coastal Fall Far North Migrating											
Age 3	-	-	-	17.6	5.4	6.6	24.4	1.7	11.8	27.7	3.0
Age 4	-	-	-	28.5	36.0	12.1	15.1	46.0	1.7	27.1	41.1
Age 5	-	-	-	5.5	19.5	33.1	10.7	18.2	50.1	4.5	19.3
Snake River Wild Fall	-	-	-	-	-	0.5	0.7	0.4	0.4	0.7	0.5

Appendix B

Relationship of the estimated abundance index with preseason and inseason measures of fishing success

This appendix summarizes the evaluation of preseason and inseason catch data as measures of the estimated abundance. Koenings et al. (1995) proposed using information on fishing success during the summer season for chinook salmon to estimate the abundance index of chinook salmon in the SEAK fishery. The measure of fishing success was termed the "400 boat index" (400BI). It was calculated by computing the total catch of each troll boat landing during the first 5 days of chinook retention in July, taking the average chinook catch from the 400 boats with the most chinook, and dividing this average by 5 (or the number of days of chinook retention which was allowed, if less than 5). This parameter had a highly significant relationship with the abundance index, with a coefficient of determination (r^2) of 0.85.

In a review of the Koenings et al. (1995) proposal, the CTC (1995) recognized that there was a statistically significant relationship between the estimated abundance index and the 400BI; however, they were concerned that the methodology of the 400BI did not account for variation in landing date versus catch date, variation in length and timing of seasons, and fishery/stock behavior on the 400BI. The CTC (1995) made a number of recommendations to improve the inseason measure of the estimated abundance index, including (1) limiting the catch index data to years in which the July catch rate would not be expected to be influenced by the "fish down" effect, (2) evaluating alternative catch data to the 400BI, and (3) examining catch index values for trends in catchability between years.

Methods

Data, including permit holder, vessel identification, date of landing, chinook salmon harvest, and Fishery Performance Date (FPD) based on sampler interviews, were taken from the ADF&G Integrated Fisheries Database (IFDB). This information was used to generate several potential indicators of inseason chinook abundance in the SEAK troll fishery. Most of these parameters incorporate harvest by vessels that landed chinook during the first 5 days of the chinook summer season troll opening. To account for the potential of a "fishing down" effect, this opening was defined as the one closest to July 1 (the date of the current summer opening) following a June closure. The dates used are shown in Table B-1 and are plotted in Figure B-1. Because inclusion of Alaska hatchery fish in the SEAK catch data could cause minor bias (CTC 1995), the catch data from the summer season were modified by reducing the catch by the proportion of Alaska hatchery chinook in the catch during the initial summer opening (Table B-2). Harvest data from 1980 through 1994 were utilized; the data from 1979 were excluded, because the fishery operated all year long in 1979 and there was no closure to set apart the summer season, which had occurred in the other years. The data series was initially truncated at 1994, because the estimated abundance index values were considered "final" through this year at the time of the evaluation. The abundance index values used for the SEAK fishery were taken from model calibration 9702 (CTC 1997).

Table B-1. Southeast Alaska opening and closing dates for the summer commercial troll season, and the dates from which landing data were tabulated to use as inseason measures of the estimated abundance index.

Year	Southeast Alaska Troll Seasons	Dates of Landings Used
1980	4/15-7/14 7/25-9/20	7/25-7/29
1981	5/15-6/25 7/5-8/6 8/20-9/3 9/13-9/20	7/5-7/9
1982	5/15-6/6 6/17-7/28	6/17-6/21
1983	5/15-6/8 7/1-8/4	7/1-7/5
1984	6/5-6/30 7/11-7/29	7/11-7/15
1985	6/3-6/12 7/1-7/22 8/25-8/26	7/1-7/5
1986	6/20-7/15 8/21-8/26 9/1-9/9	6/20-6/24
1987	6/20-7/12	6/20-6/24
1988	7/1-7/12	7/1-7/5
1989	7/1-7/13	7/1-7/5
1990	7/1-7/22 8/23-8/24	7/1-7/5
1991	7/1-7/8	7/1-7/5
1992	7/1-7/4 8/23	7/1-7/4[1]
1993	7/1-7/6 8/21-8/25 9/12-9/20	7/1-7/5
1994	7/1-7/7 8/29-9/2	7/1-7/5
1995	7/1-7/10 7/30-8/5	7/1-7/5
1996	7/1-7/10 8/19-8/20	7/1-7/5

[1] In 1992, the initial summer opening was limited to 3.5 days; all landings from chinook harvested in this period were considered, even if the landings occurred after the closure of the initial opening.

Recreational fishing catch per unit effort (CPUE) data for the Sitka sport-fishery were provided by ADF&G Sport Fish Division. CPUE was the number of chinook landed per rod hour. The data were calculated from creel census; average CPUE values were computed for statistical biweeks 10 through 12 (Sport Fish Division divides the year for data reporting into two week intervals termed biweeks), the May and June period having the most complete annual data. The rates were adjusted for the proportion of Alaska hatchery chinook using the annual proportion observed in this fishery in 1986 through 1989, and the occurrence rate for biweeks 10 through 12 for 1992 through 1994 (Table B-2).

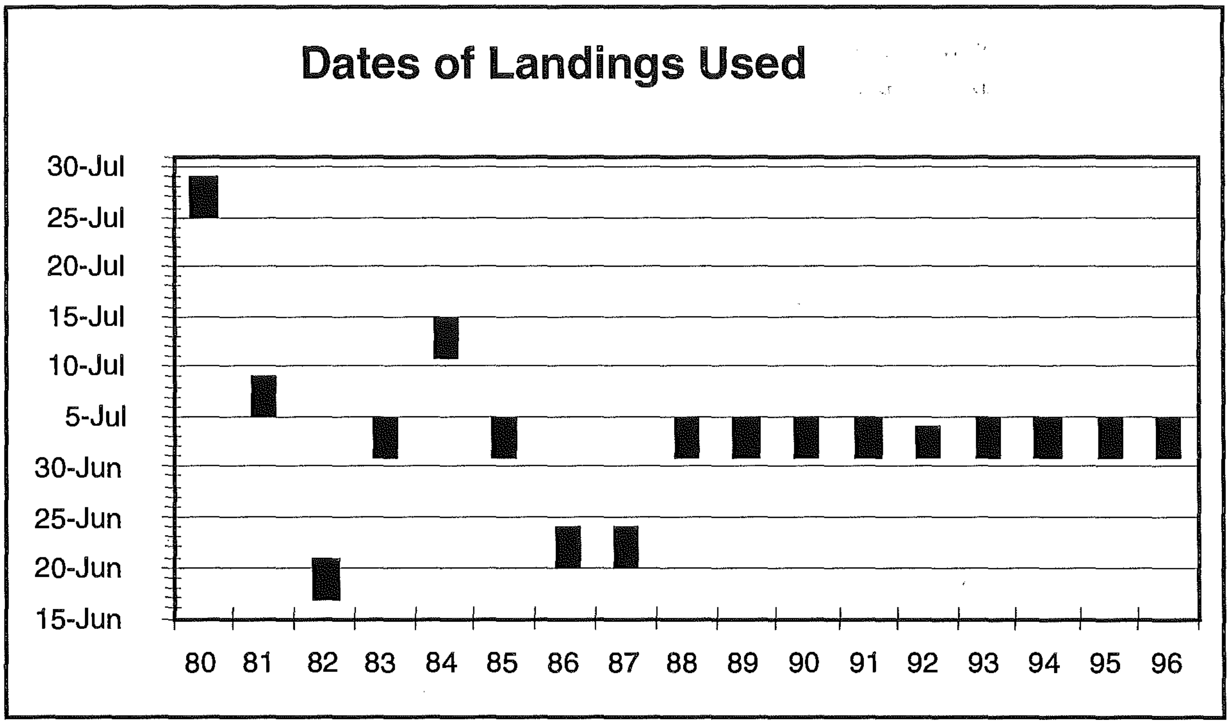


Figure B-1. Dates for which landed catches and number of permits delivering were used to calculate catch per permit for the Southeast Alaska power troll fishery.

Table B-2. Proportion Alaska hatchery fish used to adjust catch during specific portions of the commercial and recreational chinook salmon fishery in Southeast Alaska. In the Sitka recreational fishery, the annual proportion is used for 1986 through 1989 and the proportion for biweeks 10 through 12 in subsequent years.

Year	Commercial Summer (Initial Opening)	Commercial Winter (Fall Portion)	Sitka Recreational
1980	0.021	No data	No data
1981	0.002	0	No data
1982	0.005	0	No data
1983	0.006	0	No data
1984	0.007	0.01	No data
1985	0.024	0.07	No data
1986	0.037	0.07	0.010
1987	0.056	0.10	0.023
1988	0.050	0.16	0.021
1989	0.035	0.17	0.061
1990	0.065	0.18	0.080
1991	0.043	0.36	0.128
1992	0.035	0.17	0.095
1993	0.031	0.11	0.067
1994	0.043	0.03	0.051

Data on age composition and catch in the fall portion (October through December) of the winter troll season were taken from Gaudet and Sagalkin (1996). Catch numbers were adjusted for Alaska hatchery fish using the estimated proportion of Alaska hatchery chinook during this portion of the winter troll season (Table B-2).

The following measures were examined as potential predictors of the estimated abundance index:

400 Boat Index (400BI). The measure originally proposed by ADFG (Koenings et al. 1995). It was calculated by computing the total catch of each troll boat landing during the first 5 days of chinook retention in July, taking the average chinook catch from the 400 boats landing the most chinook and dividing this average by 5 (or the number of days of chinook retention which was allowed, if less than 5).

All Troll Harvest (AT). The number of chinook salmon landed during the first 5 days of the opening by both power and hand troll permit holders who landed chinook.

All Troll Harvest/Permit Statistic (ATS). The number of chinook salmon landed during the first 5 days of the opening by both power and hand troll permit holders divided by the number of permit holders who landed chinook.

Power Troll Harvest (PT). The number of chinook salmon landed during the first 5 days of the opening by power troll permit holders who landed chinook.

Power Troll Harvest/Permit Statistic (PTS). The number of chinook salmon landed during the first 5 days of the opening by power troll permit holders divided by the number of permit holders who landed chinook.

Hand Troll Harvest (HT). The number of chinook salmon landed during the first 5 days of the opening by hand troll permit holders who landed chinook.

Hand Troll Harvest/Permit Statistic (HTS). The number of chinook salmon landed during the first 5 days of the opening by hand troll permit holders divided by the number of permit holders who landed chinook.

Hand Troll Fisheries Performance Data (HTFPD). The average daily number of chinook salmon landed by hand trollers during the first 5 days of the summer opening, based on interviews of fishers landing during days 1-6.

Power Troll Fishery Performance Data (PTFPD). The average daily number of chinook salmon landed by power trollers during the first 5 days of the summer opening, based on interviews of fishers landing during days 1-6.

Sitka Recreational Fishery (SS). The CPUE in chinook per rod hour of effort in the Sitka Recreational Fishery in statistical biweeks 10 through 12.

Fall/Winter Commercial Troll Harvest (FWC). The number of chinook salmon landed by commercial fishers during the October-December portion of the winter season.

Fall/Winter Age-0.2 Catch (FW2C). The number of age-0.2 chinook salmon landed by commercial fishers during the October-December portion of the winter season

Fall/Winter % Age-0.2 (FW2%). The percentage of age-0.2 chinook salmon in the commercial catch during the October-December portion of the winter season

Summer/Fall % Age-0.2 (SF2%). The percentage of age-0.2 chinook salmon in the commercial catch during the fall (August-September) portion of the summer season.

These measures of fishing success and harvest were evaluated for simple correlation with the estimated abundance index values through 1994. The data sets used are shown in Table B-3. A correlation matrix was also structured to evaluate the association of the inseason parameters with each other. The estimated abundance index was then regressed with the 3 catch or catch/effort parameters with the highest correlation coefficients (*r*). Both untransformed and Ln/Ln transformed data were used for each regression. If the error structure associated with these data is log-normal, the Ln transformation is appropriate. Residuals were plotted to examine for time and catch magnitude trends. A stepwise regression procedure was used to determine if a multiple regression model incorporating an additional preseason or inseason parameter would improve the fit of the best single variable. Observed and predicted values from the regression model providing the best fit were then plotted, with and without the estimated abundance index and CPUE data for 1995 and 1996.

Results and Discussion

Measures of catch and CPUE from the initial 5 days of the summer season had generally high correlation with the estimated abundance index; measures from fishing periods prior to the summer opening had lower correlations. Correlation coefficients from summer season data were high, ranging from .81 through .93 (Table B-4). In contrast, commercial catch data from the fall and winter fishery had absolute *r* values ranging from 0.30 to 0.73. CPUE data from the Sitka sport fishery, which occurs in May and June prior to the summer commercial troll fishery, did have a high correlation with the estimated abundance index ($r = 0.89$, Table B-4).

The three catch measures with correlation coefficients greater than 0.9 were (1) 400 BI, (2) ATS, and (3) PTS. These measures were used in regression models as the independent variable, with the estimated abundance index as the dependent variable. Both untransformed and Ln/Ln transformed data were evaluated. These simple regression models explained a high percentage of the variability in the estimated abundance index, with r^2 ranging from 0.83 - 0.87 (Table B-5). The PTS had the highest r^2; the untransformed and Ln transformed data relationship for this parameter gave virtually identical results ($r^2 = 0.87$; Table B-5).

Table B-3. Catch and catch per unit effort data examined for correlations with postseason estimates of abundance generated by the CTC chinook model. Alaska hatchery contribution have been removed from catch data.

Year	400BI	AT	ATS	PT	PTS	HT	HTS
1980	8627.7	9714.8	11.76	6188.2	20.56	3526.6	6.78
1981	8357.0	8708.3	15.22	6584.6	22.40	2123.7	7.64
1982	10926.6	11761.7	19.00	8044.9	26.55	3716.9	11.76
1983	19578.4	21031.1	32.71	16566.5	46.54	4464.5	15.56
1984	9778.0	10359.1	16.79	7644.4	24.35	2714.7	8.96
1985	15363.1	17540.8	23.54	13412.8	32.40	4128.0	12.47
1986	12683.8	13542.4	21.67	10418.8	29.68	3123.5	11.40
1987	19487.3	21450.0	30.91	16959.9	45.84	4490.2	13.86
1988	31670.2	38232.8	44.41	29568.5	67.20	8664.3	20.58
1989	37082.5	43348.5	53.06	35770.8	78.62	7577.7	20.94
1990	31396.9	39412.5	46.92	31229.5	65.75	8183.0	22.42
1991	49338.4	63142.9	69.08	49041.7	97.11	14101.2	34.48
1992	45002.4	63356.7	57.34	55742.5	74.92	7614.6	21.09
1993	34591.1	37391.9	53.57	29715.8	79.24	7676.1	23.77
1994	31621.1	34313.4	53.12	28525.0	71.31	5788.4	23.53

Year	HTFPD	PTFPD	SS	FWC	FW2C	FW2%	SF2%
1980				3608.0			
1981	2.55	5.07		7027.0			
1982	5.23	8.27		6857.0	685.7	54.6	10.0
1983	5.94	16.74		17340.0		28.2	
1984	5.29	6.56		16981.6	5043.0	14.3	29.4
1985	4.93	8.17		6727.6	1244.2	19.9	17.2
1986	7.08	11.80	0.022	5716.7	1487.6	12.3	24.2
1987	6.95	14.73	0.018	9067.5	2821.0		28.0
1988	6.96	19.95	0.108	13174.6	3826.9		24.4
1989	5.27	24.10	0.010	8193.8	3613.2	23.6	36.6
1990	8.57	19.34		12720.7	4436.7	18.1	28.6
1991	9.62	26.60		13198.1	4701.8		22.8
1992	9.58	22.76	0.139	36149.8	4921.6	13.6	11.3
1993	7.82	18.11	0.157	37777.8			
1994	8.73	22.04	0.107	20539.8			

Table B-4. Correlation of measures of catch data with the 1980 through 1994 abundance index values from model calibration 9702.

Catch Data	Pearson's Correlation Coefficient (r)
Prior to summer season	
FWC	0.564
FW2C	0.731
FW2%	-0.348
SF2%	0.303
SS	0.890
Initial Summer Season	
400BI	0.910
AT	0.873
ATS	0.921
PT	0.856
PTS	0.933
HT	0.865
HTS	0.896
PTFPD	0.885
HTFPD	0.813

Table B-5. Linear regression of measures of catch with the SEAK abundance index from calibration 9702 of the chinook model. Years used were 1980 though1994. Catch per permit and 400 Boat Index data are for first 5 days of the summer troll season.

Catch Index	Untransformed			Ln Transformed		
	Slope	Intercept	R^2	Slope	Intercept	R^2
400 Boat Index	0.00002	0.952	0.829	0.348	-3.092	0.863
Commercial Troll Catch/Permit (ATS)	0.01631	0.88	0.848	0.381	-0.954	0.855
Power Troll Catch/Permit (PTS)	0.01192	0.856	0.870	0.404	-1.180	0.869

When stepwise regression was used in an attempt to add an additional variable, none of the measures of catch or CPUE significantly improved the univariate relationship of the estimated abundance index with one of the three highly correlated measures. The catch measures with high correlation with the abundance index were also highly correlated with each other (Table B-6), which is probably why multiple regression models did not significantly improve the univariate models.

Table B-6. Correlation matrix for measures of catch and catch per unit effort from SEAK troll fisheries.

	400BI	AT	ATS	PT	PTS	HT	HTS	HTFPD	PTFPD	SS
400BI	1									
AT	0.988	1								
ATS	0.986	0.952	1							
PT	0.980	0.996	0.941	1						
PTS	0.979	0.937	0.994	0.920	1					
HT	0.912	0.900	0.895	0.858	0.909	1				
HTS	0.940	0.900	0.968	0.870	0.965	0.942	1			
HTFPD	0.777	0.776	0.789	0.771	0.747	0.707	0.790	1		
HTFPD	0.945	0.909	0.960	0.898	0.957	0.851	0.910	0.771	1	
SS	0.882	0.797	0.913	0.764	0.906	0.840	0.922	0.406	0.715	1

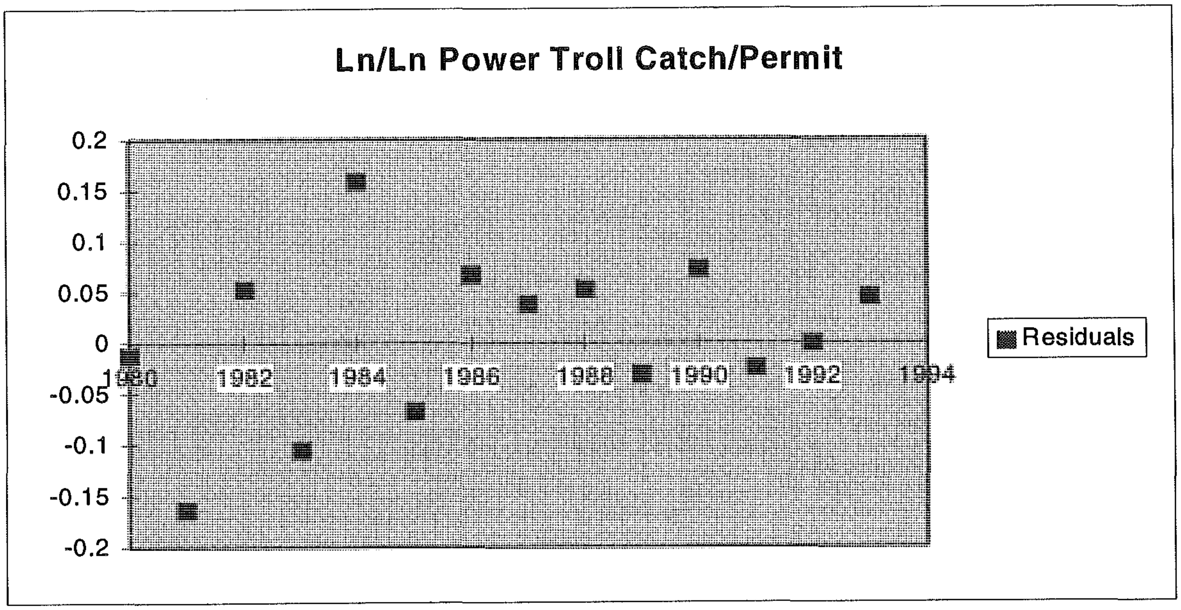
The Ln-transformed PTS was considered the best simple regression model for relating inseason catch data to the estimated abundance index using the 1980 through 1994 time series. The PTS had the highest r^2, explaining 87% of the variability in the abundance index over the time series. It has log-normal error structure, which is appropriate where the magnitude of the error around a parameter is expected to increase with the magnitude of the parameter. It also does not require ranking of catches among permits landing, which was a concern for the 400BI. By restricting catch data to the first 5 days of the summer season, the PTS, the ATS, and the 400BI minimize concern for the effect of searching behavior by the troll fleet on the magnitude of the landed catch. However, the PTS and ATS also account for the effect of interannual variation in total fleet effort (e.g., all power troll permits are considered). Because of this, they are conceptually better measures of CPUE than the 400BI, which standardizes effort to a fixed number of permits landing each year. The ATS and the PTS were actually very similar in their fit with the estimated abundance index. However, the CTC felt the PTS was a better measure because it excludes the hand troll catch and permits landing. Hand troll effort has more interannual variation and may decline over time as less nontransferable permits are fished.

The CTC (1995) previously expressed concern about apparent time trends in the residuals of the regression relationship between the abundance index and the 400BI. One possible reason the CTC identified for the time trend was the effect of "fishing down" the abundance of chinook available in earlier years of the time series, when fishing occurred immediately prior to the July fishing period used for the 400BI. Adjusting the time period used for the start of the summer troll season appears to account for this concern: no linear trend of the residuals of the regression relationship of the PTS with the abundance index is apparent over the time series of data (Figure

B-2). The only apparent pattern is a reduction in the residuals of the observed values, relative to the predicted values over time, which could be due to the consistency in the opening date of the summer troll season in later years (Figure B-1).

Another concern identified by the CTC (1995) was the possibility of search and saturation behavior of the commercial troll fleet affecting the relationship between the catch data and the estimated abundance index. Theoretically, search and saturation effects in the fleet could cause a nonlinear relationship between CPUE and abundance. If a proportional model is used to predict abundance, these effects could cause higher-than-predicted catch rates at low abundance, and lower-than-predicted catch rates at high abundance. This would result in negative residuals at low abundance levels and positive residuals at high abundance levels. The graph of residuals of the PTS and the estimated abundance index regression, in relation to the magnitude of the estimated abundance index, does not indicate that search and saturation effects have occurred over the 1980 through 1994 time series (Figure B-2).

While this analysis suggests that PTS values should be an excellent inseason predictor of the estimated abundance index, the values for the estimated abundance index for 1995 and 1996 from calibration 9702 are not consistent with the values predicted by the PTS data for these years. The estimated abundance index values for 1995 and 1996 from calibration 9702 are 0.95 and 0.90 respectively. At the PTS rates observed for 1995 and 1996, the 1980 through 1994 regression model predicts abundance index values 40% greater than those observed (Table B-7). At similar estimated abundance index values in 1980 and 1981, PTS rates were much lower (Table B-7).



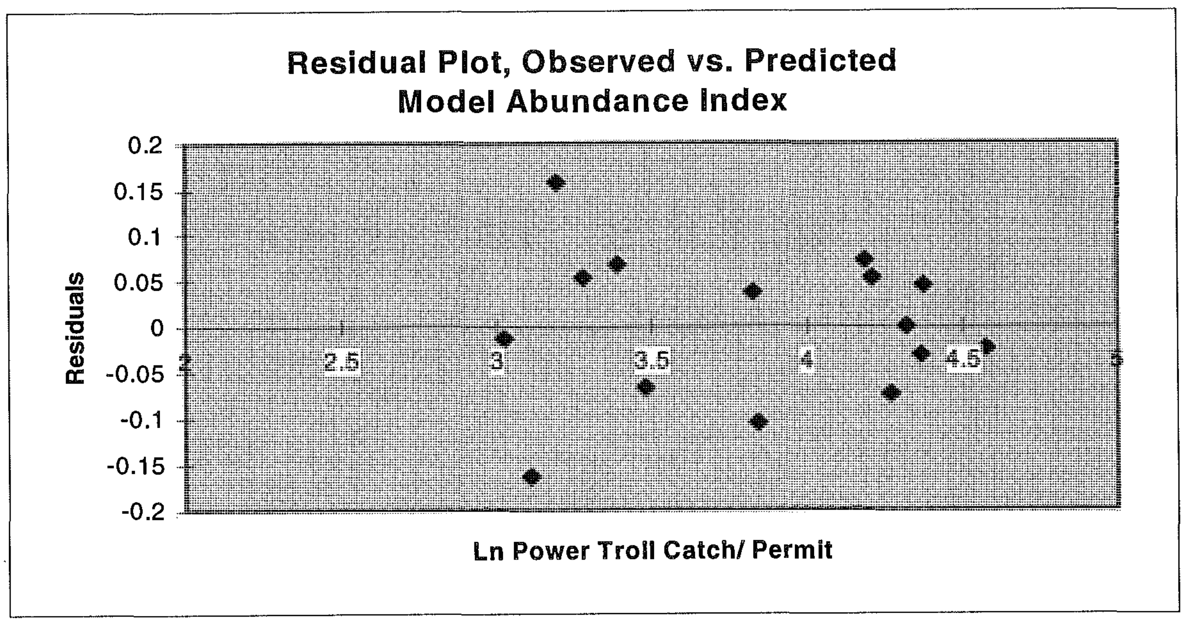


Figure B-2. Distribution of residuals of the log-transformed relationship between the estimated abundance index (1980 through 1994) and the power troll statistic (PTS) for the first 5 days of the summer troll season.

Table B-7. Estimated abundance index (AI) values generated by the CTC chinook model, and values predicted from the 1980 through 1994 Ln/Ln regression of the estimated abundance index with the PTS, for PTS observed in 1980, 1981, 1995, and 1996.

Year	Model AI	PTS	Predicted AI
1980	1.03	20.56	1.04
1981	0.91	22.40	1.07
1995	0.95	41.38	1.38
1996	0.90	42.34	1.39

One explanation for this large difference between observed and expected values in 1995 and 1996 is that estimated abundance indices in 1995 and 1996 are biased low. Low bias in the initial estimates of the estimated abundance index has been a concern raised by some members of the CTC, and it would result in the deviation from expected values to decrease, once the model calibration has complete cohort data for 1995 and 1996. The 9702 calibration, however, did not show a bias between "hindcast" forecasts of estimated abundance index and the "final" estimated abundance values.

The large deviation between the observed and expected estimated abundance index in 1995 and 1996 could also be due to random error. If the error is random, then the predictive capability of this inseason catch data is significantly lower than shown by the 1980 through 1994 time series, and thus it has much greater uncertainty than is represented by that time series. If the 1995 and 1996 estimated abundance index and PTS values are incorporated in the Ln/Ln regression, the percent of the variation described by the relationship declines from 87% to 65%.

An alternate explanation is that the true relationship between the inseason catch data and the estimated abundance index has a time trend, that is, changes over the years. There are several reasons why the relationship could be changing through time. Changes in oceanic conditions or in the relative stock contribution could cause higher susceptibility to fishing effort than was observed for similar estimated abundance index levels at the beginning of the time series. The troll fleet may have increased its fishing efficiency over the time series through improved fishing and navigation gear or increased understanding of fish distribution at the time of the summer opening. The changing timing and structure of the summer season could also affect stock composition and cause low bias in the PTS in the early years of the time series. For example, in 1981 the first summer opening following a closure did not occur until July 25 (Table B-1). Over 130,000 chinook salmon were harvested in June and July prior to a closure starting on July 15 (Dave Gaudet, personal communication, ADF&G). This large catch prior to the 5-day period used in 1980 to compute the PTS could have resulted in reduced availability of fish ("fishing down"), thus depressing the PTS value observed.

If a positive time trend does exist and is not accounted for, the simple regression model of the estimated abundance index and PTS will overestimate the abundance index. For this reason, the CTC decided to examine the inclusion of a time component to the regression model. This analysis is covered in Section 4.2.

CTC decided to examine the inclusion of a time component to the regression model. This analysis is covered in Section 4.2.

References

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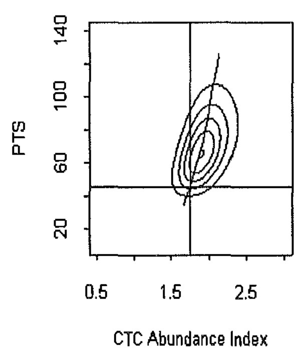
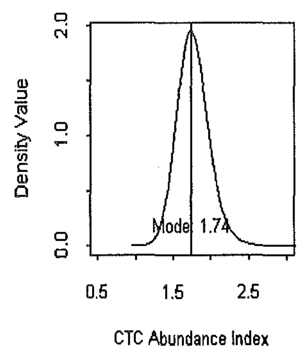
Appendix C

Bayesian bivariate density of the power troll statistic and the abundance index from the hindcasting experiment

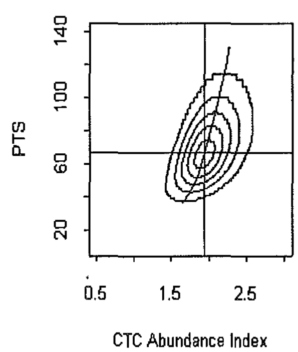
Bivariate Density Without 1987



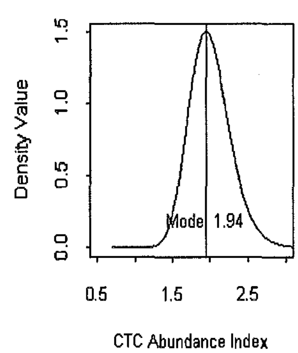
Posterior Density Without 1987



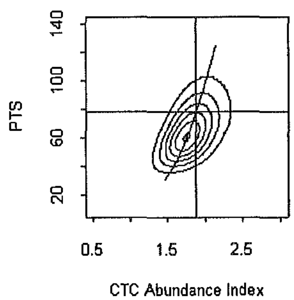
Bivariate Density Without 1988



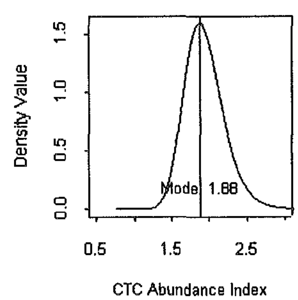
Posterior Density Without 1988



Bivariate Density Without 1989



Posterior Density Without 1989



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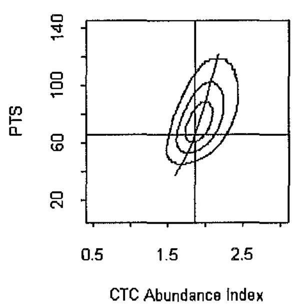
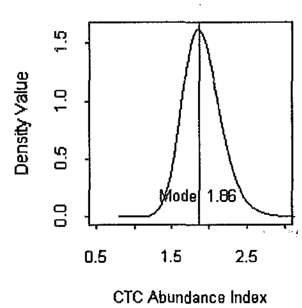
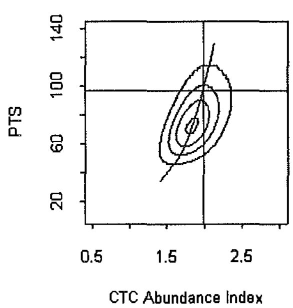


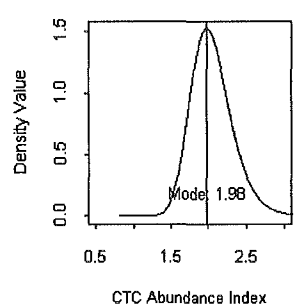
Posterior Density Without 1990



Bivariate Density Without 1991



Posterior Density Without 1991



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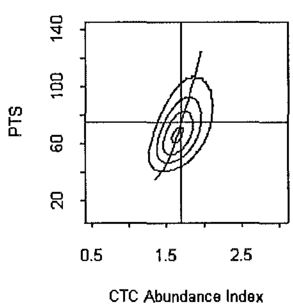

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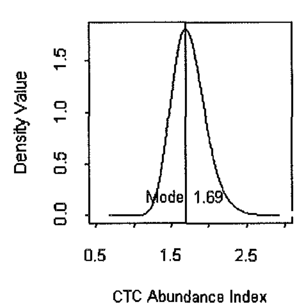

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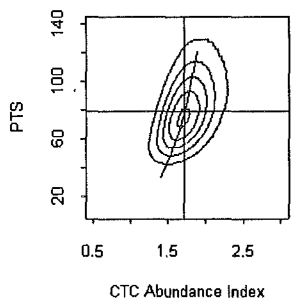
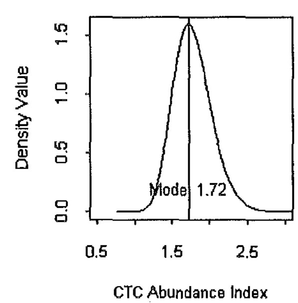
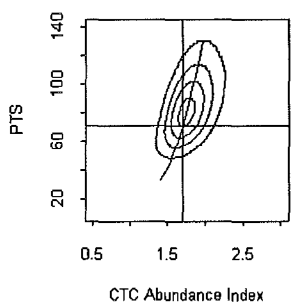


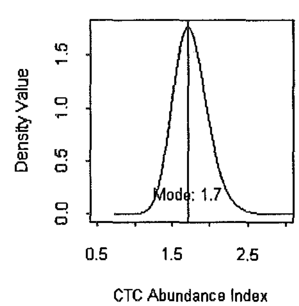
Posterior Density Without 1993



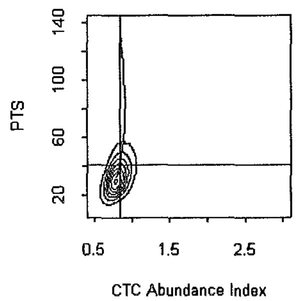
Bivariate Density Without 1994



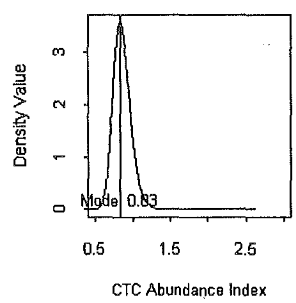
Posterior Density Without 1994



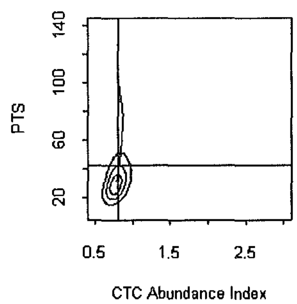
Bivariate Density Without 1995



Posterior Density Without 1995



Bivariate Density Without 1996



Posterior Density Without 1996